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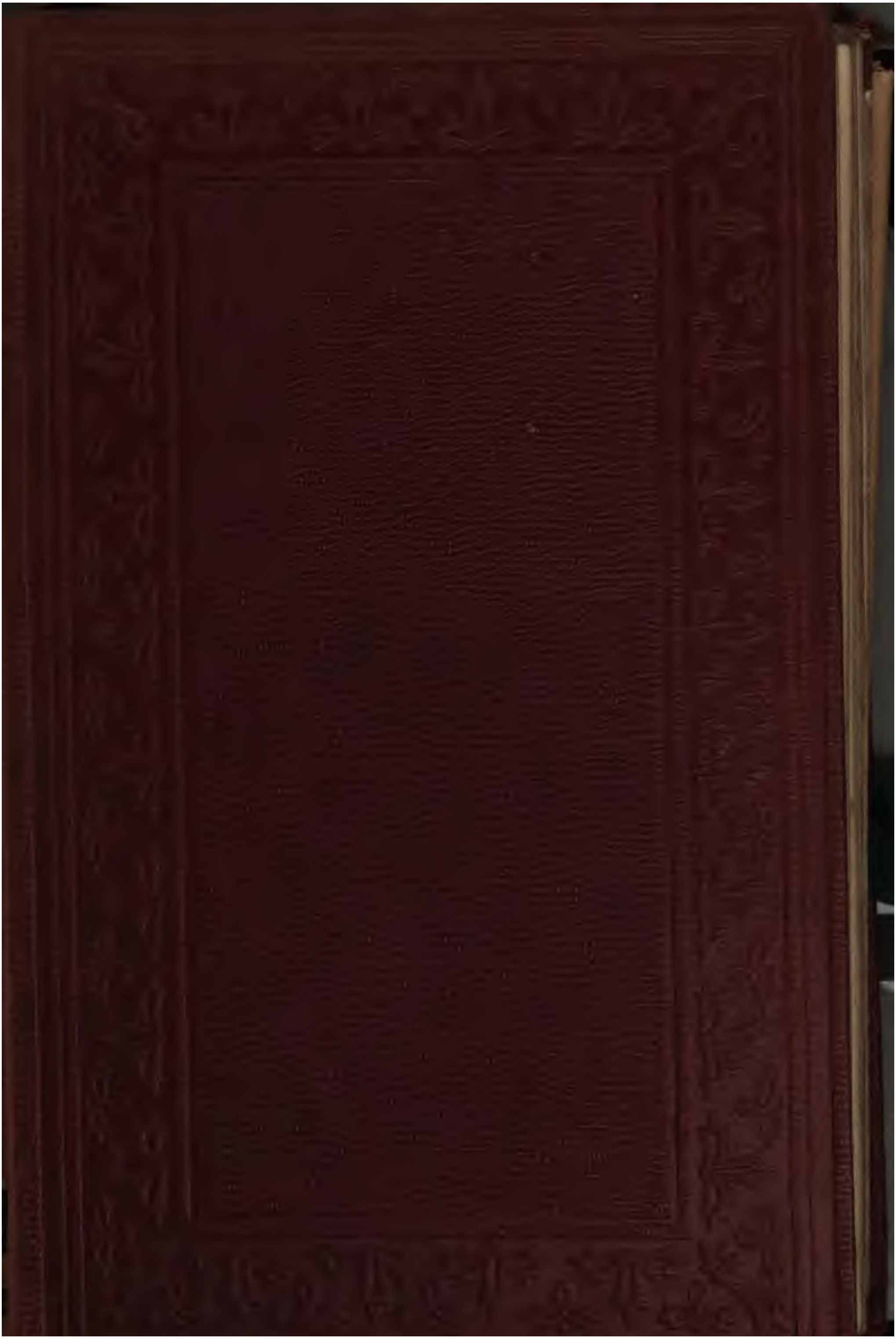


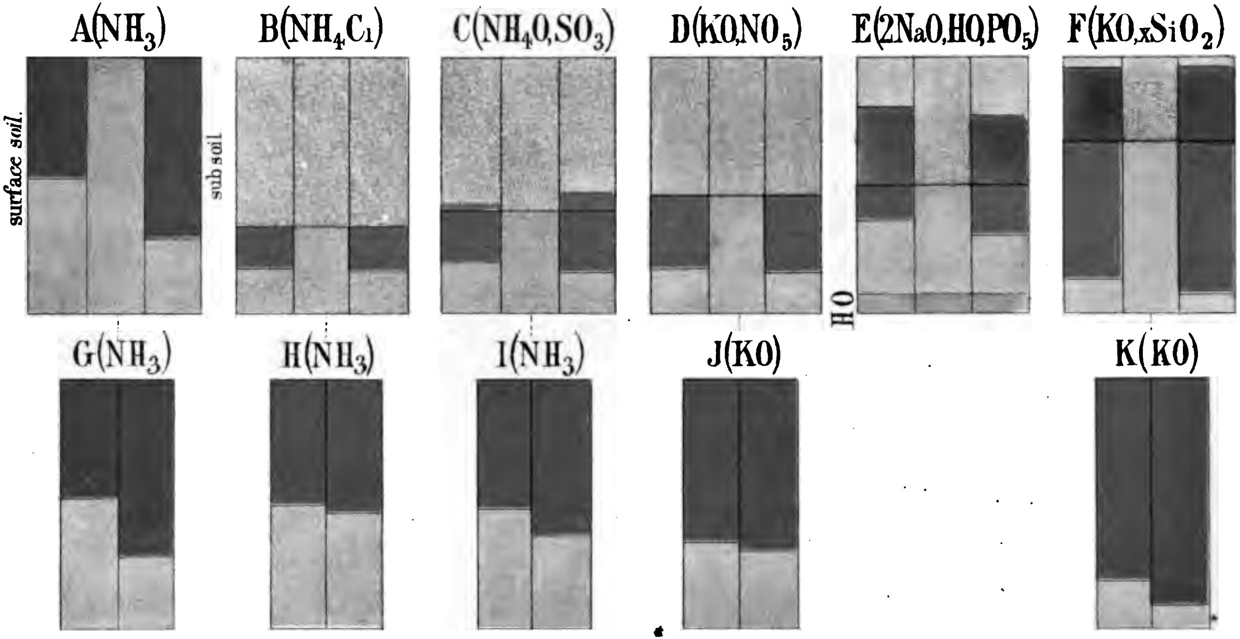
THE SCIENCE

OF

THE CULTURE OF COTTON.

Fig. 8.

ABSORPTION OF SALINE MATTER &c. FROM SOLUTION.



COTTON:

THE

CHEMICAL, GEOLOGICAL, AND METEOROLOGICAL CONDITIONS
INVOLVED IN ITS SUCCESSFUL CULTIVATION.

WITH AN ACCOUNT OF THE
ACTUAL CONDITIONS AND PRACTICE OF CULTURE
IN THE
SOUTHERN OR COTTON STATES OF NORTH AMERICA.

BY DR. JOHN WILLIAM MALLET,

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IN THE UNIVERSITY OF ALABAMA; ANALYTIC CHEMIST OF THE STATE
GEOLOGICAL SURVEY; AND CHEMICAL PROFESSOR TO THE
STATE SCHOOL OF MEDICINE, MOBILE.

LONDON:
CHAPMAN AND HALL, 193, PICCADILLY.
1862.

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~~180. b. 68.~~
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DOMINUS ILLUMINATIO MEA

TO

THOMAS BAZLEY, ESQ., M.P.,

MANCHESTER.

◆

DEAR SIR,—

THIS first part of these researches on Cotton, cannot, to any one be more properly dedicated, than to him who represents the great centre of its manufacture, and whose name is so well allied to social and industrial progress.

On the part of the absent Author, and with your permission, I therefore inscribe it to you,

And am, faithfully yours,

ROBERT MALLET.

PREFACE.

FOR the publication of this work, in its present form, I alone am responsible.

The Author a few years since, when first settled in Alabama, as a chemical professor, proposed to himself, to submit to a thorough investigation the chemistry of cotton, and all those conditions upon which its successful growth and culture depend; to such a research he brought the scientific skill, of the pupil of Lloyd, of Haughton, of Apjohn, and of Wöhler, with advantages possessed by no English chemist and physicist previously, of residence in the great Cotton States, with every facility for observation or experiment, and in familiar communication with the owners of cotton estates, with some of whom he had become connected by marriage.

He felt assured that this vast agriculture of cotton, so important to the whole human family, must be ameliorated by the light of science thrown upon it, in whatever clime or region pursued.

When in England, about four years ago, he formally stated his views to the Honourable East India Company, and asked to be provided with specimens, of the cotton plant, root, fibre, seed, &c. &c., and of the various soils and subjacent rocks, &c., from the cotton-growing districts of India. His desires were promptly attended to, and one of the latest acts, of that magnificent old Government, was to order home from all three Presidencies, in accordance with the written instructions of Dr. J. W. Mallet, such a collection of specimens, with accompanying descriptions of Oriental cotton culture, as never before reached Europe, and which were at once transmitted to him *viâ* Mobile.

Upon the same occasion, Dr. Mallet obtained through the aid of scientific friends in connexion with the Government of France, a similar, though more limited, collection from Algeria, and other French possessions, and, through the Cotton Supply Association of Manchester, others from Central or Southern Africa, and other distant regions, as well as from Egypt, &c.

With such materials, for comparison with the occidental products around him, the investigation was commenced, of which this volume forms the first fruit.

The following pages were forwarded by the author, to the writer, shortly before the breaking out of the war now desolating the American States, for communication to the Royal Society of London. Their substance was read during last session, and an abstract has been printed in the proceedings of the Royal Society. The work itself was also in the usual course submitted to "referees" by the committee of publication, one of whom is amongst the most scientific agriculturists in England, and whose report as to its scientific merits and value, is understood to have been highly commendatory.

It seemed likely, however, that the Council of the Royal Society exercising its discretion, might decide, that the work in its entirety, and from its technical character, however valuable, might not be suitable for publication in full, in the Philosophical Transactions (as originally wished by the Author), and as by rule, the copyright of any work if once submitted to the Council with a view to publication, whatever be the result, becomes the property of the Royal Society; and further influenced by the opinion expressed by friends, officers of the society, that the public value of the work would be best secured by its separate publication, the writer took upon himself the responsibility of withdrawing the communication from the Royal Society, and of arranging with the publishers for its appearance in its present form. He has had to do so without consulting the views or wishes of his son, the author, from communication with whom the war has cut him off for many months past. Dr. Mallet is still pursuing his researches, and it is to be hoped that a future volume will continue, or complete the results, embracing amongst others the requirements and effects of various manures, or dressings of the soil, indicated by the chemistry of the plant, upon the production and quality of the fibre.

The writer is himself impressed with a belief that the publication of this first part (complete in itself) of Dr. J. W. Mallet's investigations is not unimportant to public interests at this conjuncture. The facts revealed, point out how numerous and complex are the natural conditions, which must combine to admit of the cultivation, of cotton of good quality with advantage. They must tend to correct the very prevalent mistake (continually repeated by the daily press in England) that cotton can be grown *anywhere* if there be but a tropical or semi-tropical climate, the truth being, that it is a plant as limited and circumscribed by conditions of growth and seeding, as is the vine itself. To India we must undoubtedly look for a large future supply of cotton, although every discreet economist will coincide in the opinion, that a not distant conclusion of political convulsions, will still leave the Southern States the mastery in cotton supply of the world, a mastery guaranteed to them, by conditions natural and social, that cannot be imitated or transferred elsewhere; but the surface of India that is well adapted by soil, by climate, &c., to the successful culture of thoroughly good cotton, is, as was long since affirmed by the late Dr. Royle, extremely limited.

It is the function, amongst others, of these pages, to indicate what are the requirements, by which such areas in India must be characterised and chosen, and so failure of attempts in unsuitable regions avoided, and that which is by nature limited, best economised.

If, however, cotton culture in India is hereafter to become a great and trustworthy source of British supply, it can only be by a gradual but organic change, in the system of government and social fabric of India. So long as our Government there, presents but a modern counterpart of the old Roman propraetorship; whilst ever each Englishman as he arrives finds it necessary to forget his individuality, and native habits of self-reliance and original action, and only thinks of giving or of taking *orders*; so long as his aim, is not to establish himself, in any industry, wholesome to himself and improving to the country, but to make some money and "go home;" in a word, whilst ever our occupation of India is one, not of naturalisation, but of mere subjugation, and its vast resources of natural wealth are treated as little better than an official "draw farm" for the upper ten thousand, so long must cotton supply from India, remain as uncertain and as trustless, as the feeble and timid efforts of the native, whether rich or poor, in whose hands it must remain.

In fact it will present, all the evils and labour under all the difficulties, of the indigo culture—

enlarged and intensified—and with this special evil superadded, that while in the one case the final product, indigo, is under the hand and *direct* control, of the English planter, in the other, the final product, *cotton fibre*, will elude the same supervision in native hands, and its *quality* continue as inferior and uncertain as now, when from 15 to 20 per cent. of earth and dirt, is authoritatively stated as the common mixture with Surats cotton.

One reform has been made—an Englishman may now obtain land in fee in India, a measure which, if honestly given free scope, can scarcely fail to lead to other great and salutary, social and industrial ameliorations.

If India, however, is to become the rival of the Cotton States of America, or ever to be the cotton field for England, the motto *there* of its conquerors must be—

"Dwell in the land, and verily thou shalt be fed."

ROBERT MALLET.

London, February, 1862.

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THE SCIENCE OF THE CULTURE OF COTTON.

An examination of the conditions under which the cotton plant may be cultivated with success, is one of much interest, both in a scientific and an economic point of view. It is strange that science—botanical, chemical, and climatological—should as yet have supplied so little information with regard to this plant—the most important source of the clothing of man—while so many other cultivated species, many of them of far less general value, have been subjected to careful examination, their botanical relations and capability of improvement by hybridisation settled, the character and extent of their demands for atmospheric and mineral food ascertained, the soils upon which they thrive or fail analysed, the climatal conditions which favour or impede their growth observed for years; and thus a certain amount, at least, of definite scientific knowledge obtained as to the several plants and their peculiar requirements. The culture of cotton under favourable circumstances has, *as an art*, been advanced almost to perfection, yet of the scientific *principles* upon which the art is based, and from which alone success or failure in any new attempts may be predicted, we know hitherto very little. Some few scientific experiments upon cotton plants and cotton soil, have indeed been made; but they have been few and imperfect.

The main reason for this neglect of the scientific problem presented by cotton culture has doubtless been, that up to the present the world has drawn its great supplies of cotton from a new country of great fertility, offering vast surfaces of virgin soil to the hand of the labourer, and enjoying the most favourable climate for the growth of the plant which he cultivates. The ever-growing demand for this crop has, moreover, brought the planter, not merely subsistence, but wealth. The conditions have been too favourable—success has been too easy, to cause much interest to be felt in an inquiry as to how this success has been attained.

Although this state of things still exists in the Southern States of North America—the great cotton-growing region—and although a glance at any map showing the amount of land already occupied there by man, as compared with that of the untouched forest, will at once prove that no great change is to be looked for in many years to come, yet ought some interest in this problem to be felt, even in America, by any one who observes the many "worn-out" fields to be seen in all but the most recently settled States, and notes the often-met waggon of the (American) emigrant seeking new land in a newer State to be worn out in its turn. Such an agricultural system as this cannot last for ever, though, owing to the great natural resources of the country, it may long be borne. But the demand for cotton throughout the world is rapidly increasing, and America only in part satisfies it.* In the efforts so perseveringly and energetically made by England to extend the culture of cotton in her colonies, and more especially in India, greater practical difficulties have been met than present themselves in America, and success has hitherto been but partial. In connexion with these efforts a special interest attaches to the scientific questions—what are the precise conditions under which the cotton plant thrives, and how far can it be brought to bear unfavourable conditions, or these modified so as to suit its requirements?

The economic importance of the problem is foreign to the subject of a scientific treatise, it may, however, barely be noticed that it is difficult to overrate the interest of any question touching the successful production of a material which, in its husbandry, manufacture, and consumption, closely affects such an immense number of the human race.†

---

* This was written in 1860-1.

† The commercial importance of cotton culture and manufacture has been stated in a striking way by J. B. Smith, Esq., M.P., in a paper read before the Society of Arts, May 13, 1857; by

I do not propose to notice the many economical and political conditions of cotton culture upon the large scale, such as general plantation management, supply and cost of labour, provision of food for the labourers, tenure of land, irrigation, roads and other means of transportation, facilities for sale of the crop, &c.; though these, of course, materially influence success in an industrial sense.

My aim at present is merely to contribute, by the results of a few carefully-made experiments, to our knowledge of the *natural conditions under which cotton will grow and thrive.* In the first part of the research (which I have had the honour of laying before the Royal Society), and which is based upon experiments made during the winter of 1859-60—although other occupations have prevented the results being reduced to writing until now—the subject of the *soil* is taken up, and the results are given of a minute examination of the kind of soil

---

Lord Stanley, in remarks upon this paper; by T. Clegg, Esq., of Manchester, upon the authority of Mr. Bazley, M.P., at a meeting of the Society of Arts, Dec. 22, 1858; and by Mr. Bazley himself, at a meeting held in the Manchester Town Hall, the proceedings of which are reported in the *Times*, of Sept. 18, 1860.

upon which cotton is most successfully grown in America. Should these results be looked upon as of sufficient interest for reception and publication, I shall hope for permission hereafter to bring before the Royal Society (or the public) the remaining parts of the investigation, in which the composition of the ash of the cotton plant as grown in America, and the climatal relations which there affect it, will be further considered. I hope also to be able to add some results drawn from the examination of a very large and valuable collection of Indian cotton plants and soils, for which I am indebted to the liberality of the Government of India.

CHAPTER I.

NOTICE OF EXPERIMENTS UPON AMERICAN COTTON SOILS ALREADY RECORDED.

But few reliable results are to be found of attempts to analyse or otherwise examine the soils of the cotton-producing States. The most important are those of D. C. T. Jackson, of Boston, who was employed in 1857 by the United States Patent Office to make some chemical analyses of cotton plants and soils, the principal object, it was understood, being to ascertain whether the difference between long and short staple cotton depends upon the chemical nature of the substances removed from the earth.*

---

* Report of the Commissioner of Patents for the year 1857; Washington, 1858 (Agriculture), p. 296.

He examined:

No. 1.—*Soil from St. Simond's Island, Georgia, on which the Sea Island or long-staple cotton is grown.*

This soil consists of a grey sand, mixed with a fine loam, containing black particles. One thousand grains of it yield to boiling distilled water 1.6 grains of soluble matter, 1.1 grains of which consist of vegetable organic matter, and half a grain of mineral salts, consisting of chloride of sodium, phosphates of lime and soda, sulphates of soda and potash, sulphate of magnesia, and carbonate of lime, which was originally a crenate of lime.

One thousand grains of this soil yield to a boiling solution of carbonate of ammonia 3.6 grains of solid matter, two-fifths of a grain of which consist of mineral salts, as above named.

The insoluble carbonaceous matters amounted to 24 grains to 1000, or 2.4 per cent.

On full analysis, Dr. Jackson obtained from this soil—

Silica	92.040
Alumina	1.500
Lime	.280
Magnesia	.370
Potash	1.000
Soda	.500
Peroxide of iron and oxide of manganese	1.500
Phosphoric acid	.040
Sulphuric acid	.009
Chlorine	.010
Crenic, apocrenic, and humic acids	.360
Insoluble vegetable (carbonaceous) matter	2.400
Carbonic acid	Trace
	100.009

No. 2. — *Upper alluvial soil of Savannah River, on which the short-staple cotton grows, in Edgefield, South Carolina.*

One thousand grains of this soil, digested with a solution of carbonate of ammonia, yield 4.9 grains of soluble matter, 4 grains of which consist of the organic acids of the soil, namely, crenic, apocrenic, and humic acids; and nine-tenths of a grain consist of mineral matters—phosphate of lime, sulphate of lime, magnesia, oxide of iron, and the alkalies, soda, potash, and a little silica.

This soil has for its mineral constituents the disintegrated matters from the metamorphic rocks, chiefly micaceous and argillaceous slate rocks, the particles of mica being unusually abundant, but the argillaceous matters in a finely decomposed state, or in the condition of clay.

This soil yields upon analysis—

Silica	78.000
Alumina	10.040
Lime	.260
Magnesia	.200
Potash	1.000
Soda	.730
Peroxide of iron and oxide of manganese	4.850
Phosphoric acid	.310
Sulphuric acid	Trace
Chlorine	.050
Crenic, apocrenic, and humic acids	.400
Insoluble vegetable matter	4.300
	100.140

No. 3.—*Upland cotton soil, from near Jackson, Mississippi, the samples obtained from the surface down to the depth of ten inches.*

This soil is very fine loam, and, when dry, is almost an impalpable dust.

One hundred grains of it, on analysis, yielded—

Silica	81.00
Alumina	6.80
Lime	.57
Magnesia	1.60
Potash	.58
Soda	1.29
Peroxides of iron and manganese	4.18
Phosphoric acid	.38
Sulphuric acid	.07
Chlorine	.05
Crenic, apocrenic, and humic acids	.30
Insoluble vegetable matter	3.00
	99.82

The subsoil of the above, obtained 20 *inches below the surface, yielded—*

Silica	83.451
Alumina	4.100
Lime	.500
Magnesia	1.800
Potash	.790
Soda	1.450
Peroxides of iron and manganese	3.900
Phosphoric acid	.190
Sulphuric acid	.014
Chlorine	.005
Crenic, apocrenic, and humic acids	.410
Insoluble vegetable matter	3.000
	99.610

No. 4.—*Surface soil from Samuel Wood's plantation, in Hancock county, Mississippi.*

One thousand grains of this soil yielded to boiling distilled water two grains of soluble matter, or one-fifth of one per cent., and this, on incineration, yielded half a grain of ash, or five-hundredths of one per cent. The ash consists of phosphate of lime, magnesia, oxide of iron, sulphate of lime, and the alkalies, potash and soda.

Digested in a solution of carbonate of ammonia, 1000 grains of the soil produce a dark coffee-brown solution, which, evaporated to dryness, yields 10 grains of solid matter, consisting of the organic acids of the soil, namely, crenic, apocrenic, and humic acids; and on being burned off, this matter yields four-fifths of a grain of ash, consisting of the mineral salts which were combined with the above-named acids. The organic acids weigh 9.2 grains, or ninety-two-hundredths of one per cent., and the ashes, or mineral salts, eight-hundredths of one per cent.

One hundred parts by weight of this soil yielded—

Silica	88.52
Alumina	1.20
Lime	.40
Magnesia	.50
Potash	.38
Soda	1.00
Peroxides of iron and manganese	2.00
Phosphoric acid	.60
Sulphuric acid (less than $\frac{1}{1000}$)	Trace
Chlorine	Trace
Crenic, apocrenic, and humic acids	.92
Carbonic acids	.20
Insoluble vegetable matter	4.33
	100.05

Subsoil of the above.

One thousand grains of this subsoil, on digestion with a solution of carbonate of ammonia, at a boiling heat, yield 12.2 grains of soluble organic matter and salts; and, on combustion, two grains of saline or mineral matter remain, leaving for organic matters dissolved 10.2 grains. The ash contains phosphate of lime, sulphate of lime, soda, potash, and chlorine.

One hundred grains of the subsoil yield on analysis—

Silica	90.000
Alumina	2,000
Lime	.280
Magnesia	.300
Potash	.290
Soda	2.014
Peroxides of iron and manganese	1.200
Phosphoric acid	.800
Sulphuric acid	.007
Chlorine	.005
Crenic, apocrenic, and humic acids	1.020
Insoluble vegetable matter	2.790
	100.706

In 1840, Professor C. U. Shepard, of Charleston, examined eight specimens of "Sea Island" soils from Edisto Island, South Carolina, at the request of the Agricultural Society of St. John's, Colleton.*

The results were as follows:

Increase of weight after being thoroughly drenched in water.								
No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Pure Sand.
321	342	305	293	325	315	480	605	235

---

* W. B. Seabrook (President of State Agricultural Society of South Carolina): "Memoir on the Origin, Cultivation, and Uses of Cotton," p. 27. Charleston, 1844. Quoting from Southern Cabinet, vol. i. p. 405. These "soils" are also spoken of as "marsh mud."

Chemical analysis:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Silica	92.57	91.64	94.00	95.00	93.00	93.23	..	61.75
Alumina	1.70	1.70	.94	.79	.81	1.05	..	9.00
Peroxide of iron, carbonate of lime, and phosphate of lime	.70	.50	.50	.80	1.20			
Carbonate of lime	..	..	..	..	..	.35	..	.29
Phosphate of lime	..	..	..	..	..	..	..	.20
Peroxide of iron	..	..	..	..	..	..	..	5.80
Oxide of iron and phosphate of lime	..	..	..	..	..	.60		
Organic matter	2.66	3.83	1.90	1.75	2.16	2.41	8.33	9.66
Water of absorption	2.37	2.83	2.66	1.66	2.83	2.36	11.36	14.00

In the very valuable work of the late Dr. Royle upon the culture of cotton in India,* the following notice of American cotton soils is to be found:

"Mr. Piddington, of Calcutta, having received some Sea Island cotton soil (No. 1), describes it, when dry, as appearing like a mixture of fine dark-grey sand and charcoal dust, with fragments of shells, wood, both dry and charred, twigs, leaves, and even the shells of cotton seeds; but the label sent with it stated, 'In order to view this soil as it is, wet it, as though a shower of rain had fallen upon it.' Upon sifting nine ounces of this soil, eight ounces passed through muslin, as fine sand mixed with dark charcoal-looking dust. The remaining ounce was coarse sand, with fragments of shells and vegetable rubbish. Upon burning some of the dark-coloured powder in a glass tube, acrid and highly disagreeable smoke was evolved, such as characterises the peats and lignites. From this Mr. Piddington considers it to be lignite or peaty matter, in the state of very fine powder, of which a portion is readily taken up by cold water. Another specimen (No. 2) of Sea Island cotton soil, of a uniform brown colour, was also analysed.

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* J. Forbes Royle, M.D., F.R.S.: "On the Culture and Commerce of Cotton in India and elsewhere," p. 158. London, 1851.

"On analysis, 100 parts of the fine sifted part of these soils yielded:

	No. 1.	No. 2.
Saline matter, muriate of lime and soda, but no potass	.20	.60
Vegetable matter, mostly lignite or peaty powder, with a little water . . .	3.20	5.00
Iron (protoxide)	1.00	1.30
Lime (carbonate)	2.75	4.00
Alumina	.20	.63
Silex	92.00	88.02
	99.35	99.55
Water and loss . .	.65	.45
	100.00	100.00

"Mr. Piddington obtained some Upland cotton soil, from what was stated to be one of the best estates. It was a light, fawn-coloured, sandy soil, with coarse particles of silex, of felspar, and of shells, some peaty, and much divided vegetable matter, but without any saline matter. Analysis yielded:

Extractive matter, but no saline	.10
Vegetable matter, peat or lignite	4.60
Iron, protoxide	1.25
Alumina	1.00
Lime, carbonate of	2.90
Silex, coarse grains	89.35
	99.20
Water and loss	.80
	100.00

"Professor E. Solly analysed the soils of four Georgian cotton farms, obtained by Lord Palmerston from Mr. Consul Molyneux. One plantation was much elevated, the land of a deep chocolate colour, and yielding from 1000 to 1500 lbs. of seed-cotton to the acre; a second was said to produce the best cotton in the State of Georgia; a third was situated in a limestone region, 'which invariably grows a good product;' a fourth was a specimen of poor land, and the quality of its cotton is what is termed 'deficient in staple.' Mr. Solly observes, that these were all of a similar nature, their difference being merely in the relative quantity of their constituents; the structure of all was light, porous, and friable, of such a nature as to possess a considerable retentive power for water, and yet, from its openness, to allow of sufficient degree of drainage. They consist mostly of sand, the poorest of little else. They also all contain alumina, oxide of iron, and manganese, but with hardly any lime. The organic matters consist either of decayed portions of plants, &c., or very finely divided and soluble matter; these in the soils vary from 4 to 8 per cent., and in the subsoils from 1 to 1½ to 4 per cent. The soils also contain traces of saline matter."

The above are the only results worthy of confidence which I have been able to find. They are interesting, but their interest is much diminished by the incompleteness of the information they afford. The *physical* properties of the soils are very slightly indicated; their mechanical analysis is very imperfect; and the chemical analysis is far from being as detailed or precise as it should be.

CHAPTER II.

GEOGRAPHICAL AND GEOLOGICAL SITUATION OF THE DISTRICTS OF AMERICAN COTTON CULTURE (WITH MAP).

MANY published statements with regard to cotton districts in America are quite erroneous, the errors being in general due to the compilation of merely local information, furnished by those who are acquainted with their own neighbourhoods, but not with the country at large. This remark applies even to passages in Dr. Royle's work, referred to above.

In order to exhibit at once the geographical position of the regions in which cotton is cultivated, the geological character of the underlying rocks, and some of the more important facts with regard to climate, I have prepared the map which accompanies this work. The geological colouring is taken, with slight alterations, from the map of Jules Marcon,* which, although far from being correct as a whole, contains no very serious errors in the regions of cotton culture. The isothermal lines (—״—״—) of summer and winter temperature, and the lines (—∘—∘—) indicating summer and winter precipitation by the number of inches of rain, have been taken from the published results of meteorological observations made by officers of the United States army. These, however, although of immediate value and interest, belong to the illustration of a future part of this research, and do not require notice at present. The dotted line indicates the extreme limit of cotton cultivation; it was laid down from the result of the United States census of 1850, the amount of cotton, as of other crops, produced in each county being reported. This line bounds all those counties from which *any* cotton was returned. The solid line surrounds and indicates the regions of *really profitable* cotton culture, from which large quantities of the staple are drawn. Lastly, the double dotted line, the small district in which Sea Island cotton is grown.

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* Bulletin de la Société Géologique de France (1855) [2], t. xii. p. 813.

This map was prepared three or four years ago, and now would admit of correction in some particulars. I had hoped that this work might have been accompanied by a copy upon the same plan, revised to the present year, with the geology more accurately represented than upon Marcon's map, the meteorology more fully given, and with the results of the census of 1860 as to cotton culture included. These census returns have not yet been published, and in the present condition of the country it seems scarcely desirable to wait for their appearance.

Perhaps it may be possible to prepare a more perfect map in connexion with a future continuation of the research; meanwhile, the imperfections of that now furnished do not, I believe, at all affect the general conclusions to be drawn from it.*

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* I cannot avoid mentioning the extremely inaccurate idea conveyed by the map which has been published in connexion with Ellison's "Handbook of the Cotton Trade" (London: 1858). Upon a map of the world, "showing the geographical distribution of the cotton plant," "the extent of the cotton zone" is indicated by a band of colour which sweeps indiscriminately over the deserts of the Gila, the low, swampy forests of the Orinoco

The distinctive colouring of the map is explained upon it. If it be looked at in a broad way, it will be seen to indicate four distinct regions of cotton culture.

1. The narrow belt of land overlying deposits of tertiary and post-tertiary age, and extending along the coasts of South Carolina, Georgia, and a small part of Florida, upon which the valuable "Sea Island," or "long-staple" cotton is produced. This, the finest variety of the plant, is altogether a different thing from the great bulk of American cotton. It seems to be either a separate botanical species, or a very distinct variety. It has only been cultivated with success in the limited coast district in question, and in a few isolated spots similarly situated in other States; and, although in market price ranking much higher than the "upland," or "short-staple" cotton, it is grown and prepared with so much

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and Amazon, the whole of the unknown interior of Africa (excepting only the Sahara, which *is* admitted to be a desert), and the equally untrodden interior of Australia. The statement of the author in the preface that "*strict* geographical accuracy has not been attempted," may serve to explain the inclusion of the Rocky Mountains, Andes, and Himalayas in the "cotton zone."

more difficulty, and upon a scale comparatively so insignificant,* that I have as yet devoted no special attention to it, except in growing some of the seed upon "upland" soil, with a view to the future examination of the ash of the plant thus treated.

2. The extensive region underlaid by the rocks of the cretaceous system, which, it will be seen, sweeps round the south-western extremity of the Alleghany range, extending over parts of the States of Georgia, Alabama, Mississippi, and Tennessee, and reappears on the other side of the Mississippi valley in Texas. The most important rock of this region is a soft, argillaceous limestone, known as "prairie," or "rotten" limestone, above which are found the rich "prairie" lands, the name of which has come to be used in the South rather with reference to the general character of the soil itself than to the absence of timber upon it. Oaks and various angiosperms flourish in abundance in this fertile region.

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* The United States Patent-office Report for 1858 gives, as the quantity of Sea Island cotton exported in that year, 12,101,058 lbs., and of Upland cotton, 1,106,522,954 lbs.

3. The light "sandy" lands, extending over parts of South Carolina, Georgia, Alabama, and Mississippi, in great part underlaid by metamorphic rocks (gneiss, talcose, and micaceous slates, &c.), and to some extent by sandstones, and chertz limestones, of silurian and carboniferous age. In Alabama we have also, in part beneath them, a broad belt of gravel, believed to be drift, covering up the junction of the coal measures and cretaceous formations, and in the lower portions of South Carolina, Georgia, and Mississippi, the sandy beds of the tertiaries occur. These sandy lands are much poorer than the soils of the prairie region, and are in general characterised by a growth of coniferous trees, especially the long-leafed pine (*Pinus Australis*).

4. The rich alluvial lands of the "river bottoms," which are found stretching along the lower part of the Mississippi, and its more southern tributaries the Red River, the Arkansas, the White River, the Yazoo, &c., along the rivers of Texas, the Colorado, the Brazos, &c., and in Alabama and Tennessee, occupying the valley of the Tennessee river. These

bottom lands occur more or less along all the minor streams. Bottom lands are generally very fertile, but subject to inundation. Their natural growth is, on the whole, like that of the prairie region.

There are, of course, a great many subordinate varieties of soil to be met with in these four districts, but these give the broad natural divisions of the whole cotton region.

CHAPTER III.

CHOICE OF DISTRICT TO BE EXAMINED.

Of these four districts, I have selected for examination the second—that of the "prairie" soil overlying the cretaceous system—as presenting the character of a *normal cotton soil* more perfectly than any of the others. The "Sea Island" soil is doubtless worth examining, in connexion with the culture of this particular kind of cotton, but is set aside for the present as exceptional, and of minor importance if compared with the immense region of "upland" cotton planting.

The light sandy soils are of decidedly inferior general fertility. Although in wet seasons good crops of cotton are often made upon them, in periods of drought they are far excelled by the stiffer soils of prairie and alluvial character—and *the dry years are those of large cotton crops.*[*]

Alluvial or bottom soils are very fertile—the very words "Mississippi bottom" in America suggest fertility—now *a proper supply of moisture, but not in the form of rain*, is a desideratum of the first importance to the cotton plant during the greater part of its growth, as will, I think, be seen from the further part of this work—and as these bottom lands lie directly upon the rivers, or in their immediate neighbourhood, and, therefore, are constantly covered by an atmosphere supplied with moisture by evaporation from the river surface, it seems that we are more likely to get at the cause of any benefit derivable from *the soil itself* by taking specimens from a poorly-watered region, which nevertheless produces in dry seasons large and fine crops of cotton. Moreover, alluvial soils, derived from the immediate deposits of existing streams, are doubtless to a large extent variable in their nature—along the course of rivers, many of them of great length, and passing over rocks of various ages and kinds, there must be produced many deposits of different composition, even after the mixing and sifting which the finer portions have undergone as they were borne along. Bottom lands, too, are frequently overflowed, and at such times the soil of a single plantation undergoes great changes; in one place the richest silt, abounding in vegetable matter, is deposited; in another, a rapid current leaves behind it nothing but a bed of sand. These effects of inundation are not, perhaps, on the whole, injurious to a plantation—the good resulting in one place balancing the mischief done in another—but they render it more difficult to obtain a typical specimen for analysis. The selection of a fair average sample of a soil is confessedly the most difficult part of the task of the analyst, and this difficulty is perhaps less serious in the case of the prairie region than in that of almost any other that could be chosen. The prairie soils are in a state of almost impalpable division, free from stones, gravel, or coarse sand, and appear—as far as can be judged from obvious sensible characters—to be remarkably uniform over a very large tract of country.

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[*] See those remarks, which I have often heard made by practical cotton planters, expressed by the author of the pamphlet "On the Cultivation of Orleans Staple Cotton," published by the Cotton Supply Association of Manchester, p. 12.

I determined, therefore, to bestow the utmost pains upon the selection of a fair normal specimen of prairie soil, and its underlying subsoil, and to examine these as minutely and accurately as possible, believing that in this way a clue might more readily be found to the cause of the fertility of this region—so far as dependent upon soil—than by an imperfect and slurred analysis of many specimens from this and other districts. The immense amount of labour required for the complete working out of even the most simple problem, of agricultural chemistry, has constantly led to examinations of this kind being made imperfectly, in one sense or other—some chemists bestowing minute attention upon single specimens of soil, others, the majority, hastily and incompletely examining a large number. If we must curtail labour in some way, it does seem that the former is the better method of doing so, *provided* we exercise such care and judgment in the selection of single specimens, so that these may fairly be believed to represent districts of moderate extent. A good deal may be learned with regard to the cultivation of a particular plant from *exact* physical and chemical analysis of the soil of a single field, if that field be fairly represented, and we know the usual character of the crop produced upon it; but very little indeed is learned from the rough so-called analysis of a dozen specimens from different fields—the physical characters of the soils being either passed over in silence, or disposed of in a phrase or two—the state of mechanical subdivision, and the various relations to solvents of the chemical constituents, passed over equally lightly, and the results actually obtained, presented in such a form as to need calculation before they can be compared with others. The very small resultant value of the great amount of labour which has been bestowed upon the analysis of soils, has arisen from the adoption of an opinion often expressed by analysts, that it is "better to bestow time and attention upon getting the more important facts" with regard to a good many specimens, than to delay overlong upon a single one. Are we yet fairly in a position to say *which are the important facts?* In the present state of our knowledge of agricultural chemistry, is it not best to neglect altogether such soils as are obviously wanting in uniformity; to choose with the utmost care, those only which seem, as far as we can judge, to afford samples really representative of particular districts; and to examine these with completeness and minute accuracy, so that, although our results may go but a little way, they may, so far as they go, be worthy of confidence? Such results may be very far from teaching us all that we want to know, yet are the only class that can certainly show us the right direction in which to push further inquiry.

CHAPTER IV.

LOCALITY FROM WHICH SPECIMENS WERE TAKEN—THE "CANE-BRAKE:" ITS GENERAL CHARACTER.

THE locality from which my specimens for analysis were taken, is marked upon the map by a small cross. It is upon the plantation of the Hon. J. J. Ormond, in Marengo county, Alabama, in lat. 32 deg. 35 min. N., and long. 87 deg. 36 min. W.; approximately, by the State Survey, it is in section 15, township 18 of the southern division of the State, range 5, east of the meridian of St. Stephen's.

This forms a part of the district known as the "cane-brake," so called from the fact that at the time of the settlement by whites it was covered with a dense growth of cane *(Arun-*

dinaria macrosperma, Michaux). The cane-brake was not cultivated or dwelt in by Indians, apparently in consequence of the difficulty with which water could be procured. It is a region scantily watered by streams, and those passing through it are generally muddy, insignificantly small, and not permanent throughout the year. The only one in the neighbourhood of the spot from which my specimens were taken, is a little rivulet called "Dry Creek," which disappears altogether in hot weather.

Rain-water is collected by the planters in cisterns or tanks cut out of the "rotten limestone" rock, and artesian wells, frequently five hundred or six hundred feet deep, are numerous; many large plantations have four or five of them.

The uniform and very peculiar character of the cane-brake region, is strikingly seen on coming abruptly upon it, from the sandy land seventeen or eighteen miles farther north. In less than a mile, one seems to have gotten into a new country, so great is the change, from the hilly region of comparatively poor yellow sands and red clays to the almost level, gently undulating, or "rolling" surface of dark-coloured soil—often spoken of as the "black land"—with roads running through it, that in summer take such a hard, smooth surface under wheels, as literally to glisten in the sun, but in wet winter weather become banks of tenacious mud, almost impassable—at times, quite impassable—for waggons. Above all is the change in the flora noteworthy. Getting into the cane-brake, any one acquainted with the vegetation of the South might fancy himself in some river bottom, or just about to reach a stream; on all sides moisture-loving plants, among the more conspicuous being the dwarf palmetto *(Sabal Adansonii)*, the mournfully picturesque Spanish moss *(Tillandsia usneoides)*, drooping from the trees, and originally before culture, the cane, this last now almost killed out by the constant browsing upon the young shoots of cattle turned loose in the woods.

The depth of the soil—*i. e.* down to the rotten limestone rock—in this district varies a good deal, but is probably upon an average some twenty-five to thirty-five feet.

The unbroken surface of the land causes water after rains to flow over it but slowly, so that the soil is not washed away, as in more hilly regions. There are, however, little knolls to be occasionally met with where the "rotten limestone" often comes to the surface, and upon which the characteristic tree is the cedar *(Juniperus Virginiana)*, and, in some parts of the district, not in the immediate neighbourhood of the locality of soil examined, isolated little patches of gravel, elevated above the general level of the country, are to be seen. The latter were believed by Professor Tuomey,* late Geologist to the State, to be portions of the superficial (post-tertiary) deposit of loose material, which stretches across Alabama from east to west, forming, farther north, a continuous belt, which covers over the junction of the carboniferous and cretaceous rocks.

The only other peculiarity occasionally met with, is the occurrence in some places, especially in a portion of Greene county, of loose rounded masses of *hard* limestone scattered through the soil on slopes. These masses, often of the size of a man's head, being curiously perforated in various directions, are known as "bored rock." They are nearly pure carbonate of lime, as will be seen from the results of the analysis hereafter, and seem to have been segregations, from the soft calcareous mud, which has produced the rotten limestone.* These nodules of "bored rock" occur upon the plantation from which my specimens of soil were taken. They may, perhaps, cause some little local variation in the amount of lime in the soil, but they are slowly disintegrated, owing to their compactness.

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* M. Tuomey. First Report upon Geology of Alabama, p. 132; Second Report, p. 144. The latter edited by Dr. Mallet from Professor Tuomey's posthumous papers, 1857-8.

In these calcareous soils vegetable matter decomposes with great rapidity; leaves, as they fall in the forest, decay so quickly, that a horse's foot is scarcely more heard beneath the trees than if on turf; hence, no doubt, the general dark colour of the soil.

The natural forest growth of the region is chiefly white oak *(Quercus alba)*, with the red oak *(Q. rubra)*, some water-oak *(Q. aquatica)*, post-oak *(Q. obtusiloba)*, gums *(Nyssa multiflora* and *aquatica)*, elm *(Ulmus Americana)*, hickory *(Caryo tomentosa* and *alba)*, ash *(Fraxinus Americana)*, and rarely the maple *(Acer rubrum)*.

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* M. Tuomey. First Report upon Geology of Alabama, p. 122. These concretions appear to be the exact correlatives of the "conkar" of the clay loams, of the plain of the Ganges.—R. M.

As regards the character of the cotton which this cane-brake soil yields, cotton-factors of Mobile say, generally, that it is characterised by "heaviness of staple," and that the staple is rather longer than that of the sandy land. It is a desirable cotton for manufacturer's use.

The particular piece of land from which I collected specimens for examination, was new, having been cleared only the preceding winter, hence, no manure of any kind, not even the stalks and roots of a previous crop, had been applied to it. Good crops have always been obtained from the adjacent pieces of land, both when first cleared and subsequently.

CHAPTER V.

COLLECTION OF SPECIMENS FOR EXAMINATION.

The specimens were collected in the afternoon of November 8, 1858, the thermometer at about 60 deg. Fahr., the day having been cool, but becoming warmer, and threatening rain towards evening. The last rain had fallen on October 27, and was not heavy. The spring had been late, the autumn was a dry one, and the first frost was rather late (October 20). At the time of taking the specimens, both of soil and plants, the cotton was lightly touched by frost, some of the leaves dead, the bolls opening finely.

The seed that had been used was of the variety known as "Boyd cotton," eight seeds to each boll. It was planted on April 5, flowered first about June 1, the first cotton appeared in the middle of August, picking began on September 15. The plants were, as usual, about eighteen inches apart, upon four-foot rows.

Large quantities of the soil and subsoil—200 lbs. or 300 lbs. of each—were separately taken, in portions from many different spots (all appearing, however, quite uniform in character), the soil being taken from a depth of two to six inches, and the subsoil from a depth of two feet six inches to three feet. It is desirable to take the subsoil from a considerable depth on account of the great length of tap-root which the cotton plant has, sometimes extending to four or five feet. These large quantities were thoroughly mixed upon a surface of plank, and 20 lbs. or 25 lbs. each of soil and subsoil were put up in clean paper parcels, samples of one thousand grammes being accurately weighed out at the same time, and put up separately, to be used in determining the amount of water in the soil as collected.

CHAPTER VI.

PHYSICAL PROPERTIES OF CANE-BRAKE SOIL AND SUBSOIL.

In examining the physical properties of Alabama cotton soil, I have in general adopted the simple and tolerably accurate methods of Schübler,* modifying and extending these, however, in some respects. Use has been made also of the memoir of Schubze† upon similar methods; and attention has been paid to the recent experiments of Liebig‡ and others§ upon the withdrawal by soils, of saline and other substances from solution.

As my results are not in all cases, directly comparable with those of the above experimenters, it seemed desirable to examine at the same time with the cane-brake soil and subsoil, some other specimens subjected to exactly the same conditions of experiment.

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* "Grundsätze der Agricultur-Chemie," quoted by Sprengel; "Die Bodenkunde," by Boussingault, &c.

† Journal für praktische Chemie, xlvii. 241.

‡ Annalen der Chemie und Pharmacie, cv. 109; cvi. 185.

§ Henneberg and Stohmann: Ann. der Chemie und Pharm., cvii. 152; Van den Broek: Ibid., cxv. 87; Voelcker: Journal of the Royal Agricultural Society of England, xxi. (pt. 1), 105.

Five such specimens were, therefore, taken, representing soils of strongly marked and different characters; they serve as standards of comparison.

All the portions of soil operated on were *air-dried—i.e.* had remained in a room of moderate temperature (50 deg. 60 min. Fahr.) for several weeks, except in cases where the contrary is stated. All the portions required were weighed out at the same time, so as to avoid any error from alteration of the state of dryness, during the time in which the experiments were going on.

A.—General description of soils examined.

Nos. 1 and 2, from the "cane-brake," the specimens afterwards subjected to chemical analysis. Brown, or "mulatto" surface soil, underlaid by a subsoil of somewhat lighter brown colour—both become darker in tint when wet. When allowed to dry in lumps, both become extremely hard (especially the subsoil), and then *polish* when pressed upon or rubbed by a hard body; thus the roads of the cane-brake polish under the wheels of carriages.

This kind of soil works best in a *mealy* condition, when holding a large amount of water, but not enough to produce actual mud.

With a sufficient amount of water a very stiff plastic mud is formed. The extremely fine state of division of the soil is shown by the great length of time during which much of it remains suspended in water, and by the appearance of the crust upon a vessel in which this thin creamy mud has been allowed to dry; the crust then seems almost as homogeneous and adherent to the vessel as if a *solution* had been allowed to evaporate.

Much of the best cotton soil of India appears to be very similar to the above in general properties: dark-coloured, in a state of very fine division, forming a thick plastic mud with water, baking very hard when dry, &c.*

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* Dr. Forbes Watson: in papers read before the Society of Arts, March 23, 1859, and May 9, 1860—Manuscript reports sent from India, with the specimens of cotton-plants and soils which I have received from the Indian Government, confirm the statement.

No. 3.—A brown loamy soil, of moderate fertility, cultivated for several years in Indian corn, formerly cultivated in cotton. Contained a fair proportion of humus and fine sand; not much gravel or coarser material.

No. 4.—A nearly pure siliceous sand, of light yellow colour. Contained a few particles of mica, and a *very little* clay.

No. 5.—A stiff red clay, abounding in sesquioxide of iron. Contained some coarse sand, gravel, and small pebbles. Found in considerable quantity about Tuscaloosa, Alabama.

No. 6.—A stiff plastic clay, of white colour, tinged yellowish in spots by iron. Contained a moderate amount of fine, but not much coarse sand.

No. 7.—A poor sandy soil from the pine forest, of greyish colour. Little more than siliceous sand, with some organic matter, the latter for the most part undecomposed vegetable fibre, leaves, fragments of bark, or cones of the pines.

The above, Nos. 3 to 7 inclusive, were the soils chosen for comparison with those of the cane-brake. They were collected from the neighbourhood of Tuscaloosa, on the borders of the coal-measures and drift.

B.—Specific gravity (real).

The true specific gravity of the cane-brake specimens was taken in the usual way, with a specific gravity flask, using 100 grammes, dried at 100 deg. C.

The results were:

	Spec. grav.
Cane-brake surface soil . . .	. 2.421
Cane-brake subsoil	. 2.527

This being a determination of precise character, admitting of direct reference to results already recorded, it did not seem necessary to examine in the same way the soils taken for comparison. They were, moreover—unlike those from the cane-brake—so deficient in uniformity, that much larger quantities must have been taken to get accurate results. In the table of specific gravities determined by Schübler, the numbers most nearly approaching the above are those for "carbonate of lime, in a state of fine division" (ii. 468), for "arable soil from Hofwyl" (ii. 401), for "pure grey clay" (ii. 533), and for "arable soil from the Jura" (ii. 526). The mixture of different substances of course very much modifies these numbers, sand increasing the density, and organic matter diminishing it.

C.—Weight of a given volume of soil in known conditions of moisture or dryness (apparent specific gravity).

A vessel of known capacity was filled with soil, shaken down and gently pressed. This was then weighed, the tare of the vessel being subtracted.

The following table gives the weight per cubic foot of the various soils, in the *air-dried* state:

Air-dried.	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of one cubic foot in pounds avoirdupois..	76.1	82.0	77.4	91.7	81.2	81.0	65.0

In the succeeding table the corresponding statement is made for the several soils when thoroughly *water-soaked*, each having been saturated with water, and the excess of the latter drained off.*

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* The cane-brake soil and subsoil had, for this experiment, been *boiled* with water, so as to thoroughly break down all lumps; they consequently retained more water than in the regular experiments upon retentive power described further on.

In condition of greatest moisture.	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of one cubic foot in pounds avoirdupois...	94.4	94.9	106.1	118.3	108.9	109.4	99.2
Weight of water retained...	18.3	12.9	28.7	26.6	27.7	28.4	24.2

In the air-dried condition, the cane-brake subsoil has about the same density as the stiff red and white clays, while the organic matter in the surface soil, brings its density near to that of the brown loam. When soaked with water the cane-brake specimens are much lighter than any of the others. This is owing to the great amount of water which, as will be seen further on, the former are capable of retaining in their pores. The experiments, described below, on the shrinkage of the various soils by drying, will serve directly to illustrate the above result.

It being intended, to calculate the results of the chemical analysis of the prairie specimens, for the state of moisture in which they were actually taken from the field, weighings of known bulks were also made, at the time of collecting the specimens, as follows:

As freshly taken from the field.	Cane-brake.	
	Surface soil.	Subsoil.
	lbs.	lbs.
Weight of one cubic foot in pounds avoirdupois	77.7	88.2

The two specimens were measured, in as nearly as possible the natural state of compactness, the surface soil being, of course, much looser than the subsoil.

D.—Contraction of the soils on drying.

The soils were mixed to a *stiff paste* with water, moulded into cubes of two inches on the side, and allowed to dry by mere exposure to the air at 50 to 70 deg. Fahr., until they ceased to lose weight. *The prairie soil and subsoil took more than two months to dry!* They were then again measured with a scale, divided into parts equal to $\frac{1}{50}$th of an inch, *i.e.* $\frac{1}{100}$th of the original length of a side of the cube.

Calling the total original volume of each cube = 1000.

	Cane-brake		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
1000 parts by volume became	581	574	888	1000	735	793	942
1000 parts by volume *lost*, therefore, on drying......	419	426	112	0	265	207	58

The contraction is in almost all these cases high as compared with the results of Schübler, whose experiments were made with soils *saturated* with water. The extent to which the contraction of the cane-brake specimens exceeds that of all the others is extremely striking. Very great shrinkage would indeed be expected, by any one familiar with the appearance, after long-continued hot weather, of the roads through the prairie region. They open in great cracks, into which a horse may put his foot. The same observation is recorded with regard to the black soil of India.* Yet the above results of actual measurement are surprising, the cane-brake soils losing nearly half their bulk by drying.

E.—Cohesion of the soils.

The soils were moulded when moist into prisms of one inch square and two inches high, which were then allowed to dry very slowly at common temperatures. When thus air-dried, each prism, in succession, was placed on end upon a smooth plate of copper, and another thick parallel plate placed upon the upper end; pressure was then carefully applied vertically, by means of an arrangement of levers, until crushing took place.

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* The enormous shrinkage upon exposure to sun and air of the black soil of Bengal, has become but too well known, to engineers and railway contractors in India; scarcely any precaution ensures a foundation upon it; in embankments, its great and continuous recession in bulk, appears due not alone to desiccation, but also to the oxidation and removal by volatilisation (as carbonic acid chiefly) of the great proportion of vegetable matter present.—R. M.

The following weights were required to crush the several specimens:

	Cane-brake.		Brown loam.	Sand.	Red clay.*	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Crushing weights in pounds avoirdupois	456.9	501.0	195.3	15.3	215.6	220.5	37.4

Although the red and white stiff clays produced on drying, masses apparently of great firmness, they are altogether surpassed in cohesive strength by the prairie specimens, which required to crush them more than double the weight necessary for any of the others in the list. Dry clods of prairie soil are in fact almost as hard as stones, and need a hammer to break them.†

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* This result would, doubtless, have been higher but for the presence of small stones mixed with the clay.

† The "adobes," or sun-dried bricks of South America, of very similar soil, are stated to bear 500 to 600 pounds per square

The same property is possessed in a high degree by the soil from the cane-brake when moist. It is broken or cut through, with great difficulty, and thus the labour of animals employed for draught or for ploughing is rendered very severe. There is, however, a peculiar "mealy" condition, intermediate between the extremes of moisture and dryness, in which the cane-brake land can be worked with considerable ease. Hence, the importance of ploughing at just the right time, when this condition has been reached during the drying off of rain. The succeeding condition also greatly concerns the amount of labour in working such soils.

F.—Adhesion of the soils.

In order to determine the adhesion of the various soils to iron implements, ploughshares, hoes, &c., a piece of small chain, of about a foot in length, was attached to the extremity of the beam of a balance, the other end of the chain being made fast, to the centre of a disc of sheet-iron three inches in diameter. The

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inch before crushing, thus coinciding with the author's results.—R. M.

chain hanging vertically down, the disc was gently pressed into contact over its whole surface, with the specimen of soil to be examined, taken (as recommended by Schübler) in its *condition of maximum moisture* — *i. e.* having been saturated with water, and the excess of water drained off. Weights were then applied to the other extremity of the balance-beam, until the disc was pulled off from the surface of the soil by the force thus vertically applied.

The following weights were, on the average of several experiments, needed to detach the disc of iron:

	Cane-brake.		Brown loam.*	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight in pounds avoirdupois	3.3	4.5	.7	.9	1.1	1.6	.9
Adhesion per square foot in pounds	67	91	14	18	22	32	18

The cane-brake soil and subsoil probably stand so very much higher than all the others in consequence of the difficulty with which water percolates through the former; the slight pressure on applying the disc having removed some water from the surface, this was not restored to its state of maximum moisture by percolation. By repeating the experiment on the same specimen, it yielded results very far from agreeing among themselves, and this method seems to be the least satisfactory of those proposed by Schübler.

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* This low result was no doubt owing to the large amount of water *loosely retained.*

If, however, the soils be taken, not in the condition of maximum moisture, but after kneading to apparently the *stiffest possible paste, or dough*, much more concordant results are obtained. Thus the following numbers, differing greatly from the above, are, I believe, worth more for purposes of fair comparison:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight in pounds avoirdupois..................	6.8	8.4	4.9	1.4	8.9	9.6	2.3
Adhesion per square foot in pounds avoirdupois..	138	171	100	29	181	196	47

These numbers, and those of the preceding table, are all greatly higher than Schübler's, but too much importance must not be attached to results merely comparative and illustrative of one element in the labouring of these soils.

G.—Absorption of heat from the sun's rays.

The several specimens of soil—all air-dried —were placed in small paper boxes, each about six inches square and three inches deep, with thermometers having bulbs as nearly as possible alike in size and form, and each covered by about half an inch of soil. The surface of the soil in all the boxes was horizontal. The sun's altitude at noon upon the day of experiment (Jan. 16, 1860), was about 36 deg. The day was fine, still, and clear, with a bright sun—there had been a light frost the night before. The boxes of soil were screened from the sun's rays until the thermometers had all acquired the same temperature* —50 deg. Fahr.—which was also that of the air in the shade at the time of beginning the observations. The screen was then removed, so that the sun's rays fell directly upon the soils; the buried thermometers, as also one suspended in the air (in the shade), were then read off at intervals of ten minutes, the readings being made accurately to one-fifth, and by estimation to one-tenth of a degree.

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* The small *absolute* difference of reading of the thermometers, when exposed to the same temperature, was noted, and is corrected for in the table.

The readings are given in the following table:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.	Air in shade.
	Surface soil.	Subsoil.						
	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.
11 h. 30 m. A.M.	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
— 40 m. —	54.0	54.0	53.8	56.7	54.2	54.7	56.5	51.0
— 50 m. —	59.1	58.6	59.1	61.0	59.2	57.8	61.0	52.0
12 h. 0 m. (noon) ..	63.3	62.5	63.4	63.7	62.7	61.1	64.5	52.6
— 10 m. P.M.	67.0	65.5	66.4	65.7	64.8	63.5	66.2	53.0
— 20 m. —	69.3	67.5	68.5	67.5	67.2	65.0	67.8	53.5
— 30 m. —	71.0	69.3	70.3	68.5	68.8	66.0	69.0	54.0
— 40 m. —	73.0	71.3	71.9	69.7	69.5	67.5	70.1	55.0
— 50 m. —	74.7	73.0	73.9	70.9	71.0	68.2	70.8	55.3
1 h. 0 m. —	75.9	74.2	74.8	71.4	71.2	68.5	71.5	55.8
— 10 m. —	77.0	75.4	75.7	71.7	71.2	68.8	72.1	56.0

By subtracting the number of degrees attained at the end of each period of ten minutes, from that reached at the end of the next period, we get the following table of differences, showing the successive increments of temperature experienced by the several specimens for the intervals of time mentioned:

Increments of heat in—	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.	Air in shade.
	Surface soil.	Subsoil.						
	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.
1st ten minutes	4.0	4.0	3.8	6.7	4.2	4.7	6.5	1.0
2nd do.	5.1	4.6	5.3	4.3	5.0	3.1	4.5	1.0
3rd do.	4.2	3.9	4.3	2.7	3.5	3.3	3.5	.6
4th do.	3.7	3.0	3.0	2.0	2.1	2.4	1.7	.4
5th do.	2.3	2.0	2.1	1.8	2.4	1.5	1.6	.5
6th do.	1.7	1.8	1.8	1.0	1.6	1.0	1.2	.5
7th do.	2.0	2.0	1.6	1.2	.7	1.5	1.1	1.0
8th do.	1.7	1.7	2.0	1.2	1.5	.7	.7	.3
9th do.	1.2	1.2	.9	.5	.2	.3	.7	.5
10th do.	1.1	1.2	.9	.3	..	.3	.6	.2
Total for 100 minutes	27.0	25.4	25.7	21.7	21.2	18.8	22.1	6.0

It will be seen that the sand, and the very sandy pine-forest soil, begin to absorb heat most rapidly; but the amount absorbed soon falls off. The same is true of the white and red clays, though in a less degree. The brown loam and the cane-brake specimens, especially the latter, exhibit the most steady and gradual absorption of heat, and in the end they become hotter than any of the others.

Several of the soils show a greater increment of temperature in the second, or even third, period of ten minutes, than in the first; this is, no doubt, due to the evaporation of a little water, carrying with it heat, as the *first* effect of the sun's rays. The influence of a sudden increase in the heating power of the sun's rays —from increased clearness of the atmosphere, or some such cause—is seen in the higher numbers for the air, as well as for the soils, in the seventh period of ten minutes.

As the absolute temperature attained at the end of the whole period of observation varies for the different soils, the *rate* at which each becomes heated will be better seen from the following table, showing the per-centage amount of rise of temperature of each soil in given times, as referred to the total increment of temperature of each respectively, considered equal to 100:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.	Air in shade.
	Surface soil.	Subsoil.						
	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.
1st ten minutes	14.82	15.75	14.79	30.88	19.81	25.00	29.41	16.67
2nd do.	18.89	18.11	20 62	19.82	23.58	16.49	20.36	16.67
3rd do.	15.55	15.35	16.73	12.44	16.51	17.55	15.84	10.00
4th do.	13.70	11.81	11.67	9.22	9.91	12.77	7.69	6.67
5th do.	8.52	7.87	8.17	8.29	11.32	7.98	7.24	8.33
6th do.	6.30	7.10	7.00	4.61	7.55	5.32	5.43	8.33
7th do.	7.41	7.87	6.23	5.53	3.30	7.98	4.98	16.67
8th do.	6.30	6.70	7.73	5.53	7.08	3.73	3.17	5.00
9th do.	4.44	4.72	3.50	2.30	.94	1.59	3.17	8.33
10th do.	4.07	4.72	3.50	1.38	..	1.59	2.71	3.33
Total in 100 min. assumed	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

From this it appears that the cane-brake soil, and subsoil respectively, acquire in the first ten minutes about 15 and 16 per cent. of their entire rise of temperature for one hundred minutes, while sand acquires about 31 per cent. During the last ten minutes of the hundred, the sand gains rather less than 1½ per cent., and the red clay has altogether ceased to rise in temperature; while the surface soil from the cane-brake gains 4, and the subsoil nearly 5 per cent.

Throwing the preceding results into a graphic form, we get the curves in Fig. 1, in which the

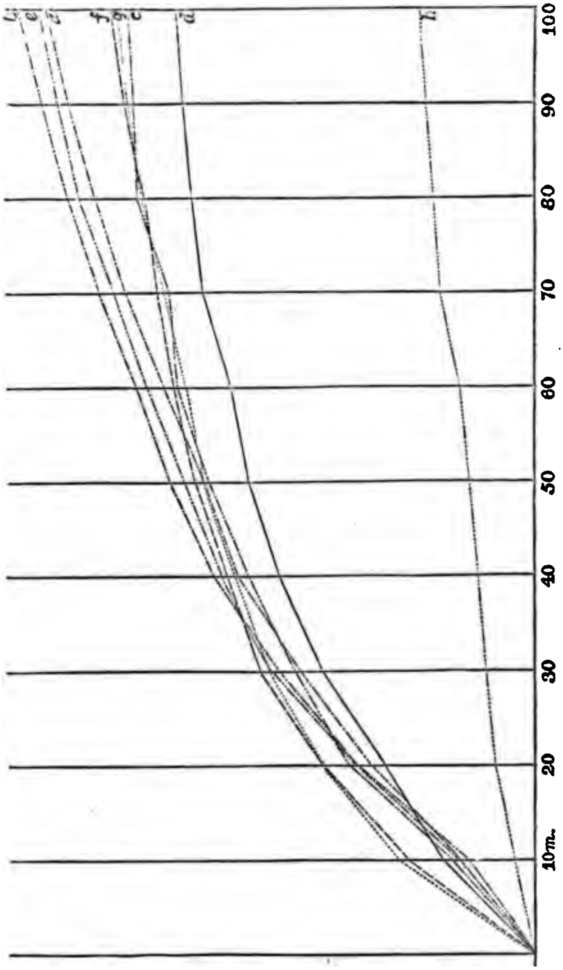

FIG. I.—ABSORPTION OF HEAT.

a. Subsoil. *b.* Surface soil. *c.* Red clay. *d.* White clay. *e.* Brown loam.
f. Pine woods soil. *g.* Sand. *h.* Air.

horizontal ordinates represent time, and the vertical, increments of temperature. The curves for the two cane-brake specimens and the brown loam are not far apart, those for the sand and pine-forest soil keep closely together throughout; that for the red clay runs with the first group for sixty minutes, and then turns off to join the sandy soils; the curve for the white clay is peculiar throughout, showing an absolute temperature, lower at each given time than that of any of the others.

The above experiments show that it is important to observe, not only the *absolute temperature attained*, but also the *rate of increase* of temperature of a soil when exposed to the sun. The statements of Malaguti and Durocher,* in opposition to Schübler, that mineral composition has a more important influence than colour, upon absorbing power, and that sand becomes more highly heated than clay, appear to be true only if the two be examined, soon after the rise of temperature has begun; after a while the cane-brake soils become hotter than the sand. The dark *colour* of the former is, no doubt, the main cause of their high absorbing power; the same influence is seen in the high temperature attained by the brown loam.

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* Comptes-rendus, t. xliii. p. 1110.

H.—Retention of heat.

The rate at which the several specimens of soil lose heat was determined in the following way: A little box of tin-plate—a cube of three inches on the side, holding, therefore, 27 cubic inches of soil—was filled with the specimen to be examined, taken in the air-dried state, slightly crushed to remove large lumps, but not pulverised, shaken down, but not pressed into the box. A delicate thermometer with spherical bulb was passed through a hole in the upper side, or lid of the vessel, and fixed so that the bulb was exactly in the centre of the mass of soil. The vessel was attached to little handles of low conducting power for heat; it was then placed in an air-bath, and heated equally on all sides until the thermometer, buried in oil, indicated a temperature several degrees above 130 deg. Fahr. The vessel was removed from the air-bath, and placed in a room of considerable size, the temperature of the air in which remained near to 50 deg. Fahr. (48 deg. to 53 deg.) throughout the experiments. The time at which the buried thermometer marked 130 deg. was noted, and again the time at which 60 deg. was reached; the interval was the time required by the soil under experiment to cool down 70 deg.

The numbers in the following table express the times of cooling in minutes for the quantity of soil and under the conditions mentioned above:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	min.	min.	min.	min.	min.	min.	min.
Time, in minutes, of cooling down to 70 deg. Fahr.	123	137	98	101	121	114	104

Thus, the brown loam, the sand, and the pine-forest sandy soils, cool most rapidly; the stiff clays of white and red colour come next in order; and the surface and subsoils of the cane-brake cool more slowly than any of the others.

The above comparison applies to *equal volumes* of the soils; from these numbers, and the apparent densities already given, we may roughly compare the times of cooling of *equal weights*, assuming the rates of the preceding table to hold.

The lower line of the following table gives the times required by 1000 grammes of each soil, to cool from 130 deg. to 60 deg. Fahr.:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
Weight of 27 cubic inches in grammes	539.1	581.2	548.8	649.9	575.3	574.0	460.7
Time, in minutes, taken by 1000 grammes to cool down to 70 deg. Fahr. ..	228	236	179	155	210	199	226

This mode of discussing the results obtained, principally affects the position in the table of the sand and pine-forest soils, the heaviest and lightest of the samples examined; the former cooling at a higher relative rate for equal weights than for equal bulks; the latter exhibiting a rate of cooling so much diminished as to bring it close to the cane-brake surface soil.

The results just given, differ altogether from those of Schübler, as to the relative rates of cooling of sand and clay; the former, according to him, taking a much longer time to lose a given amount of heat than the latter. Repetition of the experiment, however, produced concordant results; the stiff cane-brake soils standing highest on the list as regards retention of heat.

A good deal of the accuracy of the experiment depends upon care being taken that the specimens remain long enough in the air-bath to become fairly dry; if they are still losing water by evaporation, when set away to cool, heat will of course be very rapidly carried off. Much also depends upon the like degree, of looseness or compactness, with which the soils are introduced into the vessel, in which they are to be cooled.

These results, of course, do not indicate the relative extent to which these soils would become cooled at night when exposing a free radiating surface to the sky. The loss of heat in this case will depend upon radiating power, conducting power, and specific heat; the latter two only, are involved in the experiments made by the above method—that of Schübler—the soil being surrounded on all sides by tin-plate, from the surface of which the radiation takes place. It would be interesting to examine this subject more minutely, and I hope to be able to return to it as a general question in connexion with the physics of the soil.

I.—Absorption and retention of water.

The specimens of soil were gently crushed, so as to break down large lumps; portions of 100 grammes of each were weighed off in the air-dried state: these were thoroughly drenched with water upon a thin filter, and then allowed to drain until water ceased to drip from them. Being weighed against a thoroughly wet filter of the same kind and size, used as tare, the maximum amount of water which each soil could hold in its pores was obtained. The soils were then transferred to shallow dishes of stout tinfoil, and spread out so that each specimen exposed a surface of ten square inches. They were allowed to remain in a room the air of which was at 50 deg. 60 min. Fahr., and were weighed at stated intervals, as they gradually dried—the amount of water lost by evaporation being thus determined.

The weighings are in grammes, and are given as they were made—to centigrammes —though it is not pretended that the figures in the second decimal place are of importance.

	Cane-brake*		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
Commencement of the experiment	154.68	154.10	142.51	136.39	145.95	148.35	151.00
After 6 hours	147.78	147.42	134.80	129.19	138.55	140.46	144.76
12 "	144.71	145.08	132.70	126.90	136.19	139.01	142.91
24 "	141.27	138.19	127.69	118.82	129.64	133.08	134.82
48 "	129.20	126.34	117.34	105.54	118.96	122.19	124.51
72 "	124.31	121.59	112.38	101.49	114.42	117.21	115.99
96 "	121.61	119.11	109.95	100.55	111.91	114.66	112.03
120 "	119.04	116.80	107.57	100.27	109.55	112.04	108.90

Subtracting each number from the one which precedes it in the same vertical column, we get the amount of water retained by 100 grammes of soil, at each of the times mentioned as follows:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
Total amount of water retained at commencement..	54.68	54.10	42.51	36.39	45.95	48.35	51.00
Lost from commencement to 6 hours	6.90	6.68	7.71	7.20	7.40	7.89	6.24
6 hours to 12 hours	3.07	2.34	2.10	2.29	2.36	1.45	1.85
12 " to 24 "	3.44	6.89	5.01	8.08	6.55	5.93	8.09
In first 24 hours............	13.41	15.91	14.82	17.57	16.31	15.27	16.18
24 hours to 48 hours........	12.07	11.85	10.35	13.28	10.68	10.89	10.31
48 " to 72 "	4.89	4.75	4.96	4.05	4.54	4.98	8.52
72 " to 96 "	2.70	2.48	2.43	.94	2.51	2.55	3.96
96 " to 120 "	2.57	2.31	2.38	.28	2.36	2.62	3.13
Remaining after 120 hours..	19.04	16.80	7.57	.27	9.55	12.04	8.90

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* The cane-brake soil and subsoil are capable of holding much more water when thoroughly *disintegrated by boiling* with water in the first instance. Merely *pouring* water over them, even with stirring, will not break down these tenacious soils into a uniform mud.

Thus, to take a single instance from the table, 100 parts of cane-brake surface soil in the air-dried state* are capable of holding 54.68 parts of water, of which are lost by evaporation, under the conditions mentioned above, 6.90 parts during the first six hours, 3.07 parts in the second period of six hours, 3.44 in twelve hours more; or, in all, 13.41 parts in the first twenty-four hours, 12.07 parts in the second entire day, 4.89 in the third, 2.70 in the fourth, and 2.57

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* 100 grammes of the several soils in the air-dried condition correspond to the following weights of soils dried at 100 deg. C.:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
Weight of 100 grammes of air-dried soil, dried at 100 deg. C.	91.66	90.22	98.01	99.63	97.59	97.93	98.71

If now we add the amounts of water thus shown to exist already in the air-dried soils to the quantities absorbed by these when thoroughly drenched (as given in the table above), we get the following as the total amounts of water which would be absorbed by 100 grammes of each soil dried at 100 deg. C.

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
Water absorbed, in grammes	68.75	70.80	45.40	36.83	49.55	51.40	52.97

in the fifth, leaving 19.04 parts still retained after five days' drying. The large amount of water which can be held by the cane-brake soils, without draining off, is manifest from the table, although the difference in this respect between these and the other soils examined is much more striking, if we take into account the hygroscopic water already condensed in the pores of each (*vide* foot-note, preceding page).

The slowness with which the cane-brake specimens part with the water they have taken up is particularly to be noticed. After exposure to the air for five days they still retain 17.19 parts of water, while the next most retentive specimen—the stiff white clay—retains but 12 parts, and the sand is as dry as at first. The importance of this property in a hot climate, suited to the culture of cotton, is obvious.

The gradual drying of these highly-retentive soils will best be seen from the following table, in which, assuming the amount of water retained by each soil at the outset equal to 100, the proportional amount of this retained at each period of weighing is given:

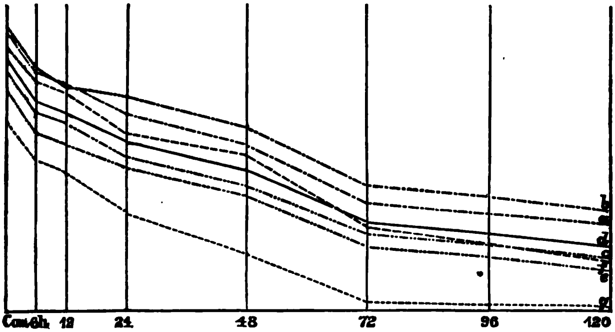
	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
Total amount of water at commencement assumed..	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Of this, lost from commencement to 6 hours..........	12.62	12.35	18.14	19.79	16.10	16.32	12.24
6 hours to 12 hours	5.61	4.32	4.94	6.29	5.14	3.00	3.63
12 „ to 24 „	6.29	12.74	11.78	22.24	14.25	12.26	15.86
Commencement to 24 hours.	24.52	29.41	34.86	48.32	35.49	31.58	31.73
24 hours to 48 hours........	22.07	21.90	24.35	36.49	23.24	22.52	20.21
48 „ to 72 „	8.94	8.78	11.67	11.13	9.88	10.30	16.71
72 „ to 96 „	4.94	4.58	5.71	2.59	5.46	5.27	7.76
96 „ to 120 „	4.70	4.27	5.60	.77	5.14	5.42	6.14
Commencement to 120 hours	65.17	68.94	82.19	99.30	79.21	75.09	82.55
Water still retained........	34.83	31.06	17.81	.70	20.79	24.91	17.45

The above results, thus variously discussed, show that the cane-brake soils exceed all the others examined, both in the power of absorbing and retaining liquid water. The pine-forest soil, owing to the organic matter which it contains, comes next in point of absorbing power, and then in order, the stiff white and red clays, the brown loam, and lastly the sand; but as regards power of retaining water, the order is altered by the pine-forest soil falling to a position next the sand.

The curves of fig. 2 illustrate these points; the horizontal ordinates represent time, and the vertical the quantities of water absorbed and retained.

FIG. II.

ABSORPTION AND RETENTION OF WATER.



a. Subsoil. *b.* Surface soil. *c.* Red clay. *d.* White clay.
e. Brown loam. *f.* Pine-woods soil. *g.* Sand.

J.—Rate at which water percolates through the various soils.

In connexion with absorbing and retaining powers it is, of course, important to examine the ease or difficulty with which water passes through the soil, as this will determine the time required for one portion to be affected by the dryness or moisture of neighbouring portions.

To get the rate at which water sinks through the soil by its own weight merely, it was at first attempted to filter through a depth of several inches of soil, contained in a tube of an inch in diameter, closed at the bottom by muslin; but it was found that the rate of filtration was so very slow as to render the experiment most inconveniently tedious, and to bring in evaporation of the water as an important source of error. Hence the following plan was substituted. A filter, of Swedish paper, of 7½ inches in diameter was taken, a circle of 7 inches in diameter, and another circle of 4½ inches in diameter were drawn upon it with pencil, both concentric with the circumference; this filter was then folded, and placed very smoothly in a funnel, which it exactly fitted.

Air-dried soil (crushed, not pulverised) was then filled in, just up to the lower (4½ inch) circle.

A second funnel was supported over the first, closed at bottom by a little piece of indian-rubber tube, and compression stop-cock. This was filled with water, and the water allowed to flow down upon the soil in the filter until the liquid stood exactly at the level of the upper (7 inch) circle, at which level it was kept by the stop-cock throughout the experiment. *As soon as the rate of filtration had become uniform*, which in the stiffer soils was only after several minutes, a graduated glass jar was placed under the filter; the moment of doing so was noted, the time when ten cubic inches of water had filtered through was also noted, and the intervals were found as follows:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	min.	min.	min.	min.	min.	min.	min.
Time, in minutes, required for filtration of 10 cubic inches..................	74.0	82.3	29.4	9.6	26.3	47.7	13.1

This method is not altogether satisfactory; the filtration through each portion of soil is complicated to some extent with filtration down the sides of the paper filter through its substance, even though care be taken to place it in close contact with the glass funnel. Still the above numbers give a tolerably fair idea of the relative ease with which water filters through the several soils. If the source of error just mentioned were removed, the difference between the individual results would be all the more striking.

K.—Rate at which water is drawn through the soils by capillarity.

The capillary power of a soil is clearly a physical property of much interest, since by it the upper portions of the mass are enabled to draw moisture from those below, and, in general, by its means motion of water in the soil is produced during dry weather. The attention of Schübler was directed to this point in connexion with his extended research, but he failed, I think, to fairly estimate the function of capillarity in drawing water through a mass of soil, and, confounding together two different ways in which the character of the soil may influence capillary action, he arrived at a general result by no means expressing the whole truth. He says* that the capillary power of a soil depends principally upon the fineness of its particles, the spaces between which may be looked upon as equivalent to so many minute tubes; and he adds, that in order to determine this capillary power for any particular kind of soil, the latter in a dry and finely-divided state is to be placed in a glass cylinder, open at both ends, and pressed moderately together; the cylinder is now to be placed in a vessel with a little water, and from the rapidity with which the soil draws up the water, the proportionate capillary power is to be recognised.

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* Quoted from Sprengel, Die Bodenkunde (2te Aufl.), s. 297.

From the fact that the water rises more rapidly when the soil has been placed loose in the cylinder, than when it has been strongly pressed together, he draws an argument for deep working with the subsoil plough.

Carrying out Schübler's idea, samples of the air-dried soils (crushed, not pulverised) were pressed down, with moderate compactness, into a tube of six inches long and one inch in diameter, closed at bottom by a little round patch of thin cotton cloth, just large enough to cover the end, and held tightly in place by a slender ring of copper. The tube was suspended vertically, and the lower end (that covered by cotton cloth) kept *just* in contact with the surface of water in a large platinum dish, which with its contained water were weighed after each five minutes' contact with the water surface. The amount of water absorbed by the cotton cloth was determined and allowed for. The rate of evaporation of the water was also determined and corrected for. The successive amounts of water lost by the platinum dish gave, of course, the quantities sucked up by the soil.

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
Water, in grammes, taken up in 1st five minutes	2.37	2.16	7.35	19.34	8.33	6.38	12.14
„ 2nd „	.73	.57	2.01	6.47	3.56	2.12	3.50
				25.81[*]			
„ 3rd „	.52	.45	1.73	..	2.38	1.52	2.75
„ 4th „	.43	.29	1.62	..	1.73	1.26	2.08
„ 5th „	.39	.26	1.24	..	1.41	1.09	1.69
„ 6th „	.35	.21	1.13	..	1.14	.97	1.41
Total in thirty minutes	4.79	3.94	15.08	..	18.55	13.34	23.57

Discussing these results, as those of other experiments, with a view to exhibiting more distinctly the relative *rates* at which the different specimens draw up water, we get the following table:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.
Per-centage amount of water in 1st five minutes........	49.48	54.82	48.74	74.93	44.91	47.82	51.51
„ 2nd „	15.24	14.47	13.33	25.07	19.19	15.89	14.85
				100.00			
„ 3rd „	10.85	11.42	11.47	..	12.83	11.40	11.67
„ 4th „	8.98	7.36	10.74	..	9.33	9.45	8.82
„ 5th „	8.14	6.60	8.22	..	7.60	8.17	7.17
„ 6th „	7.31	5.33	7.50	..	6.14	7.27	5.98
Total in thirty minutes *assumed* equal to	100.00	100.00	100.00	..	100.00	100.00	100.00

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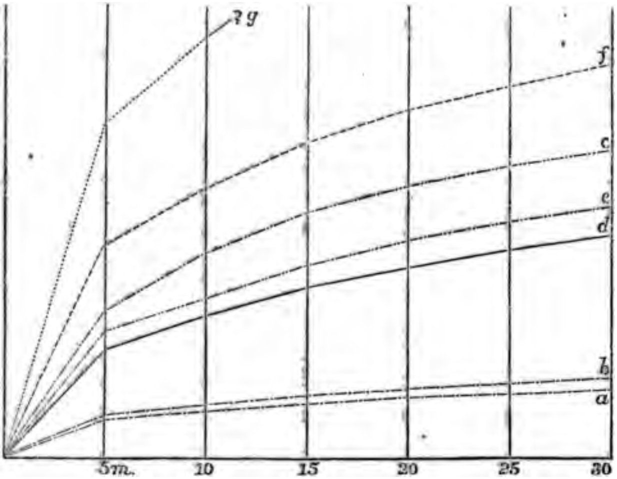
[*] Experiment stopped; water had risen to the top of the tube.

FIG. III.

CAPILLARITY (APPARENT).



a. Subsoil. *b.* Surface soil. *c.* Red clay. *d.* White clay.
e. Brown loam. *f.* Pine-woods soil. *g.* Sand.

Fig. 3 illustrates the above results graphically: the horizontal ordinates stand for intervals of time, and the vertical for amounts of water drawn up by capillarity. It will be seen from these curves, and from the numbers upon which they are based, that the compact soils of the cane-brake—the particles of which are excessively minute,* draw up water by capillary action much more slowly than loose sand, the grains of which are comparatively very large,* and that in general the coarser and looser is a soil, the more rapidly is water drawn through it. This result quite agrees with the statement of Schübler, as to the effect of looseness or compactness of the soil as packed into the cylinder for experiment; but both are altogether opposed to the other—undoubtedly correct—statement with which he introduces his notice of capillary power, namely, that this power depends upon the *fineness* of the particles of soil, the spaces between which may be considered as minute tubes. The smaller a

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* *Vid. infrà,* results of mechanical analysis.

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* In order to see whether the low apparent capillary power of the cane-brake soil and subsoil was owing to the large amount of water already existing in their pores, the foregoing set of experiments was repeated with these, *after careful drying* at 100 deg. C., with the following results:

	Surface soil.	Subsoil.
Water, in grammes, taken up in the 1st five minutes . .	2.94	2.49
" 2nd " . .	.87	.77
" 3rd " . .	.58	.55
" 4th " . .	.48	.44
" 5th " . .	.42	.39
" 6th " . .	.37	.35
Total in 30 minutes . . .	5.66	4.99

There is a little more absorption than with air-dried specimens, but nothing approaching that of the other varieties of soil.

tube or little vessel of any shape is, the higher will be the column of liquid which may be supported within it, by the form of adhesive attraction which we call capillarity; and hence the actual capillary *power* of a mass of loose material—such as a soil—must be greater when its particles, and consequently the spaces between them, are minuter than when the reverse is the case. But the particles of any ordinary clay are far finer than those of sand; and this is pre-eminently true of the stiff cane-brake soil. It is obvious, on reflection, that the *force* with which water is drawn up through a mass of soil, and the *rapidity* with which the water is so drawn, are two different things, and that the latter by no means exclusively depends upon the former.

The so-called, attraction of adhesion, draws water along upon the surface of each little particle, filling one after another the minute interstitial spaces; in each such space the molecules of water *in contact with the sides* (*i. e.* with the surfaces of surrounding solid particles) are supported by this curious form of attraction, in opposition to the forces of gravity and cohesion influencing the molecules *in the middle.* When the latter forces balance that of adhesion, the creeping upwards of the water ceases; the smaller, therefore, are the spaces to be filled, the less will be the weight of water filling them to be supported by adhesion to their sides, and the higher will be the column of water drawn up. But, if the spaces become exceedingly small, the influence of adhesive attraction in those already filled will extend to so much of the water passing through them, that the forward motion of the liquid molecules, caused by the attraction of surfaces beyond, will be but slow; in fact, friction will become so considerable as to *retard* materially the passage of the fluid, though the force of adhesion may still be amply sufficient to carry it higher.

It has been already shown that water *is* drawn up *more rapidly* by soil in a coarse, than that in a fine, state of division; it remains to be seen whether the latter can raise the water *higher* or not—that is, whether it possesses a practically greater capillary *power.*

L.—True capillary power of soils.

The following mode of examining the question just stated was suggested by the interesting research of Jamin, on the motion of fluids in porous bodies.*

A glass tube of about an inch in diameter and six inches long, open at both ends, being taken—the lower end was closed by a patch of thin cotton cloth, held on by a little ring of copper—the soil was carefully filled in, and moderately pressed down, the top was closed by a cork (made air-tight with sealing-wax), through which passed a small tube, bent at right angles; this tube was joined by an indian-rubber connector to a small pressure gauge, consisting simply of a U-shaped tube, about an eighth of an inch in diameter, open at both ends, and containing mercury. The whole arrangement is shown in fig. 4. The larger tube, holding the soil, was supported in a vertical position—the end closed by muslin being downwards—a vessel of water was then placed under

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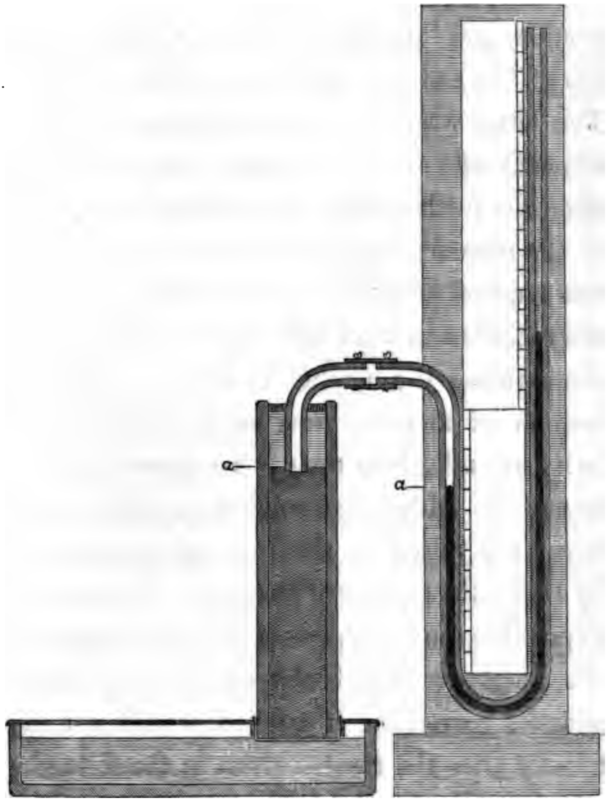
* I regret my not having been able to procure Jamin's original memoir, an abstract of which only I have seen in the American Journal of Science [2], xxix. 418 (Correspondence of J. Nicklès).

FIG. IV.

Mode of determining true Capillary Power.



it, and gradually raised until the lower end of the tube just dipped into the water, and the time at which this was done was noted. As the water rose into the pores of the soil, the air previously filling them was driven upwards and compressed into the pores of the still dry portion, and into the little space* between the top of the soil and the surface of the mercury. The latter was, of course, depressed upon the adjacent side of the U-shaped tube, and raised upon the further side. The difference of level of the mercury in the two limbs of the gauge was read off at stated intervals, and the results are recorded in the following table, its numbers representing the heights, in inches, to which a column of mercury was supported by capillarity at each given time. To these should, of course, be added the heights to which water was itself raised in the tube of soil, divided by 13.6—the density of mercury. It was found impossible, however, to observe with exactness the height to which the soil became wetted, and the correction, if applied, would not materially alter the results given in the following table:

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* The air filling this little space—from *a* to *a* on the figure —amounted at the beginning of each experiment to about half a cubic centimètre.

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	inchs.	inchs.	inchs.	inchs.	inchs.	inchs.	inchs.
Height of mercury in inches, at the end of 5 minutes ..	..	..	..	1.12	1.98	1.69	1.43
" 10 " ..	..	..	..	1.23 1.25 13 m.	2.73	2.56	1.57
" 15 " ..	..	..	..	..	3.18	3.22	1.65
" 30 " ..	.89	.78	1.27	..	3.97	4.33	1.76
" 45 " ..	..	..	..	..	4.44 4.75 59 m.	4.91	1.81 1.82 47 m.
" 1 hour 0 " ..	1.42	1.26	2.39	..	..	5.28 5.51 1 h. 26 m.	
" 1 " 30 " ..	1.79	1.61	3.18				
" 2 " 0 " ..	2.08	1.87	3.91				
" 2 " 30 " ..	..	..	4.24 4.33 2h. 50 m.				
" 3 " 0 " ..	2.50	2.28					
" 4 " 0 " ..	2.85	2.65					
" 5 " 0 " ..	3.16	2.98					
" 6 " 0 " ..	3.38	3.25					
" 24 " 0 " ..	4.82	5.25					
" 48 " 0 " ..	5.98	6.72					

If a porous mass, subjected to the above conditions of experiment, were made up of particles, all of the same size, and the spaces between them were in like manner uniform, it is obvious that the mercury should rise higher and higher in the outer limb, of the U-shaped tube, until the weight of the column supported, plus the weight of water supported in the soil itself, just balanced the force of capillary attraction which raised the water; then the mercury should come to a stand, and remain at rest. But, in fact, the particles constituting a soil, are very far from uniform in size or form, and the interstitial spaces are correspondingly unequal; hence the above experiments were stopped in each case, by *bubbles of air making their appearance on the surface of the muslin which covered the lower end of the tube of soil, and escaping through the water.** It was clear that, while capillary force, as exerted *in the larger interstitial spaces*, had been balanced by the height to which the mercurial column had been raised, *the smaller spaces* beyond were still capable of drawing up water under greater pressure; this increased pressure the water in the larger spaces could not bear, and the compressed air, instead of raising the mercury higher, was forced back through these larger cavities, which now served as tubes of exit.

The times at which the several experiments were thus stopped are mentioned in all cases, except those of the cane-brake soil and subsoil; in these the water was still slowly rising at the end of forty-eight hours, and the experiments were not continued longer. Although, of course, the same result would after a time have followed with these specimens, the fact that it did not occur for forty-eight hours, while the brown loam—the soil which among the others bore the increasing pressure longest—broke down at the end of two hours and fifty minutes, is a striking proof of the great uniformity of minute texture possessed by the cane-brake soils, and increases the confidence with which results of their examination may be viewed as representative of the district.

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* When the first bubble escaped, the mercury fell somewhat in the U-shaped tube; it then continued to rise and fall slightly as each successive bubble, was with difficulty formed, and made its escape.

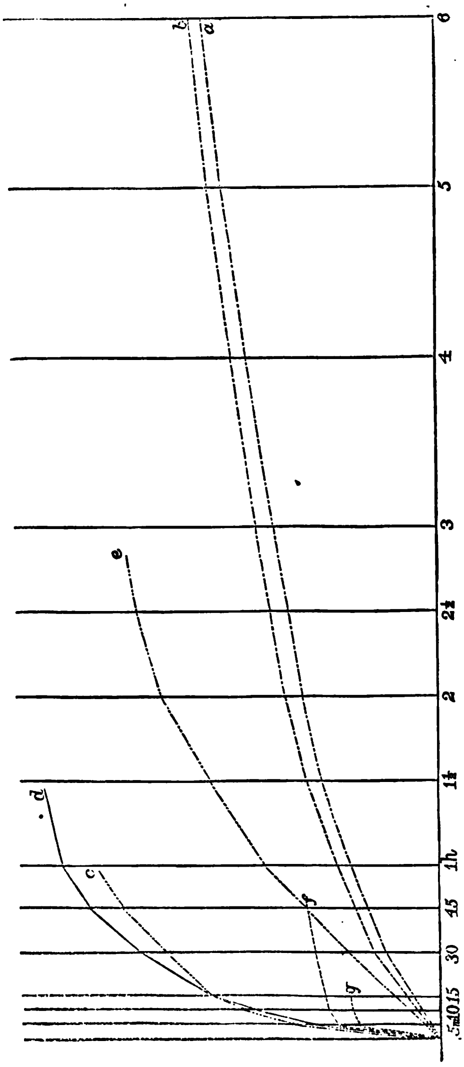
A glance at the table of results, shows at once that the idea already expressed is fully borne out, namely, that finely-divided soils raise water by capillary action slowly, but practically with great power; while those of coarse texture act rapidly, but practically with feeble energy. As water is drawn up into the coarsely porous sand, the mercury rises in the first five minutes a little more than an inch, but at the end of ten minutes it is very little higher than before, and in thirteen minutes it ceases to rise altogether, air then escaping through the large pores. In the case of the brown loam, the mercury after half an hour, is scarcely higher, than in that of the sand at the end of five or ten minutes: but it continues steadily to rise, and when at two hours and fifty minutes it stops, it is nearly four times as high as it could be raised by the capillary power of the sand. The cane-brake soil and subsoil, produce still less disturbance of the mercury for the first half-hour or hour, but they are *still taking up water at the end of forty-eight hours*—and the latter has raised a column of mercury nearly seven inches high—the exact result being *equivalent to a column of water of seven feet seven inches in height!*

In figs. 5 and 6 it has been attempted to represent the foregoing results graphically, but the effect to the eye is marred, by the necessity for altering the value of the horizontal ordinate—of time—in fig. 6, which exhibits the latter part of the experiments with cane-brake soil and subsoil; the value assigned on fig. 5, if continued, would require a sheet of most inconvenient length.

It will be seen that the lines representing the course of capillary absorption, for the two highly sandy soils, are close together, those for

FIG. V.

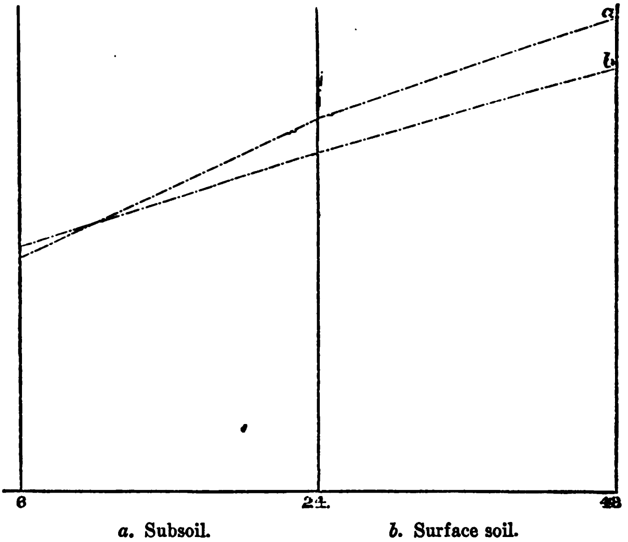
True Capillary Power.



a. Subsoil. b. Surface soil. c. Red clay. d. White clay. e. Brown loam.
f. Pine-woods soil. g. Sand.

FIG. VI.

Capillary Power.



the stiff white and red clays are near each other; that for the brown loam is different from the others; and those for the two canebrake specimens are distinguished by the slowness with which they rise, to become, however, ultimately higher than all the rest.

The facts brought out by the above experiments, have an important bearing upon the agricultural capabilities of all soils. In a hot climate, and especially in one presenting a very unequal distribution of rain—a peculiarity which constitutes a serious objection to the climates of many regions, that are yet hot enough for cotton culture—it is obvious that a soil in a state of very *fine and uniform division* will possess marked advantages over one consisting of coarse particles of unequal size. The latter will quickly become saturated during rain, but in dry weather, will soon draw up such store of water as it has acquired, and can raise to the surface, there to be evaporated, and so lost to the roots of plants. The former—such a soil as that of the cane-brake region—*will gradually but forcibly draw up its supply of water from deep-lying strata, and slowly dispense it* to the surface soil, thus using, it may be, in the burning heats of August or September, the moisture which it had steadily absorbed during the rains of the preceding winter or spring.

The one soil is a spendthrift, rapidly acquiring, and as hastily and extravagantly scattering; the other is a prudent economist, gradually accumulating, and expending slowly and with caution. Again—if one may be pardoned carrying out the same simile a little further—as the goods of the spendthrift are likely in time to fall into the hands of his more steady neighbour, so is it in the case of the two opposite kinds of soil under consideration. If a mass of finely divided uniform soil, adjoin one of loose sandy character, the latter will become a reservoir, from which—at depths practically incapable of being reached by its own feeble capillary power, its neighbour, the highly absorptive clay, will continue to draw supplies of water, to be by it, easily raised to the surface. Yet further, the remarkable power possessed by soils of abstracting various mineral substances from their respective solutions (see further on in this work), so far, at least, as it depends upon phenomena of adhesion, is doubtless possessed in the highest degree, by finely divided soils; moreover, this power must be most efficiently exerted, when the water charged with soluble matter, is most slowly passed, through the pores or interstitial spaces, such as we have seen exist, in the case of the finest clays, when drawing through them water by capillary action. If, then, two soils of the opposite characters mentioned above, should occur side by side, will not water, holding in solution some of the inorganic substances needed by growing plants, be gradually drawn off, from the soil of small, by that of great capillary power? In fact, will not the tendency be towards the rich soil becoming continually richer, and the poor one poorer? It would be highly interesting to repeat the above experiments on capillarity, with solutions of alkalies, salts, &c., instead of pure water, observing both the physical and chemical effects in each case. This I hope hereafter to be able to accomplish.

M.—Absorption of aqueous vapour from the air—hygroscopic power.

Small trays made from thick tinfoil, were prepared, about half an inch deep, and exactly five inches square, so that soil uniformly spread over the bottom, exposed a surface of twenty-five square inches to the air. The various soils were slightly crushed, but not pulverised,* dried at 100 deg. C., weighed off in quantities of 100 grammes upon the several trays, and uniformly spread out in each. The trays were then all placed together under a large glass bell, beneath which had been previously set, a shallow porcelain dish containing water; the latter remained throughout the experiment, so that thus the soils were alike exposed, to an atmosphere under ordinary pressure, saturated with aqueous vapour, at the temperature of the room, which was 50 to 60 deg. Fahr.

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* Wherever this expression is used, it means that all lumps larger than a pea were crushed down, care being taken not to triturate any portion of the soil.

After the lapse of the times stated in the following table, the trays were removed from the bell-glass, weighed, and immediately replaced. The successive weighings exhibit the gradual absorption and condensation of water from the air, as below:*

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* A few experiments were also made, under the same conditions, with regard to the absorptive powers for aqueous vapour, of the cane-brake soil and subsoil, taken in their air-dried state, with a view to determining whether this power was permanently affected by exposure to a temperature as high as that of boiling water. The following were the results:

	100 grammes air-dried.	
	Surface soil.	Subsoil.
After 12 hours	100.32	100.43
„ 24 „	100.49	100.63
„ 48 „	100.77	100.95
„ 72 „	100.95	101.20
„ 96 „	101.06	101.37

	100 grammes dried at 100 deg. C.						
	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
After 6 hours	102.16	102.89	101.01	100.24	101.16	101.07	100.82
„ 12 „	103.01	104.06	101.32	100.29	101.60	101.36	100.97
„ 24 „	104.13	105.59	101.64	100.31	102.08	101.67	101.08
„ 48 „	105.65	107.52	102.03	100.33	102.61	102.03	101.22
„ 72 „	106.68	108.56	102.27	100.34	102.94	102.16	101.25
„ 96 „	107.21	109.05	102.29	100.34	103.35	102.29	101.28
„ 120 „	107.62	109.49	102.31	100.34	103.64	102.42	101.35
„ 20 days	110.23	111.61	102.67	100.34	104.62	102.59	101.46

The subjoined table of differences, shows the actual weights of water absorbed, as aqueous vapour, in the given periods of time, and the totals:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
0 hours to 6 hours	2.16	2.89	1.01	.24	1.16	1.07	.82
6 „ to 12 „	.85	1.17	.31	.05	.44	.29	.15
12 „ to 24 „	1.12	1.53	.32	.02	.48	.31	.11
0 „ to 24 „	4.13	5.59	1.64	.31	2.08	1.67	1.08
24 „ to 48 „	1.52	1.93	.39	.02	.53	.36	.14
48 „ to 72 „	1.03	1.04	.24	.01	.33	.13	.03
72 „ to 96 „	.53	.49	.02	..	.41	.13	.03
96 „ to 120 „	.41	.44	.02	..	.29	.13	.07
120 „ to 20 days	2.61	2.12	.36	..	.98	.17	.11
Total in 20 days	10.23	11.61	2.67	.34	4.62	2.59	1.46

The very much greater amount of aqueous

The above amounts, added to the quantities of water driven off from the air-dried soils, by a temperature of 100 deg. C. (*vide suprà*), agree very nearly, with the total quantities taken up for the same period of exposure, by the specimens dried in the first instance, at the higher temperature.

vapour condensed by the cane-brake soils, than by any of the others in the list, is very striking, being, at the end of twenty days, *twice and a half* as much as that absorbed by the stiff red clay, the next most absorptive specimen.

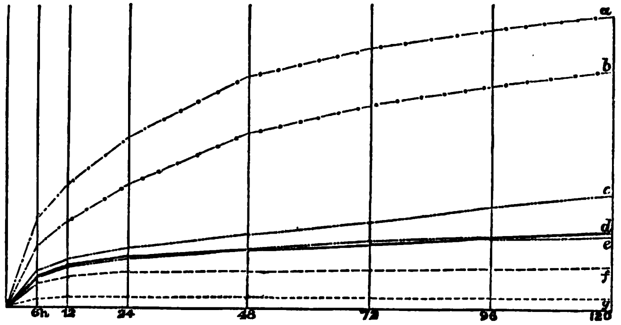
The difference in the *rate of absorption*, is to be seen from the following table, discussing these results, as former ones, by dividing the total amount of vapour condensed by each soil, assumed = 100, in proportion to the time in which absorption took place:

	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grme.	grms.	grms.	grms.
0 hours to 6 hours	21.11	24.90	37.83	70.59	25.11	41.31	56.17
6 ,, to 12 ,, ...	8.31	10.08	11.61	14.71	9.52	11.20	10.27
12 ,, to 24 ,, ...	10.95	13.18	11.98	5.88	10.39	11.97	753
0 ,, to 24 ,, ...	40.37	48.16	61.42	91.18	45.02	64.48	73.97
24 ,, to 48 ,, ...	14.86	16.63	14.61	5.88	11.47	13.90	9.59
48 ,, to 72 ,, ...	10.07	8.91	8.99	2.94	7.14	5.02	2.06
72 ,, to 96 ,, ...	5.18	4.23	.75	..	8.88	5.02	2.06
96 ,, to 120 ,, ...	4.01	3.80	.75	..	6.28	5.02	4.79
120 ,, to 20 days	25.51	18.27	13.48	..	21.21	6.56	7.53
Total for 20 days (assumed)..	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Thus, the cane-brake soil and subsoil, absorb in the first six hours, but 21 and 25 per cent. respectively, of the entire amount which they can take up in twenty days; while the brown loam in six hours absorbs 38, and the sand, over 70 per cent. of the total amount they are capable of taking up. The former absorb at first absolutely more, but relatively less, than the latter. The former, if damp weather last for some time, will continue to condense aqueous vapour, after the latter shall have ceased to take up any appreciable amount. In general, the soil which will in the end absorb most vapour, absorbs it most gradually; whereas the soil which absorbs with (relative) rapidity at first, will in the end take up but little.

FIG. VII.

ABSORPTION OF VAPOUR FROM THE AIR.



a. Subsoil. *b.* Surface soil. *c.* Red clay. *d.* White clay.
e. Brown loam. *f.* Pine-wood soil. *g.* Sand.

The graphic exhibition of these results, up to the term of five days,* is to be found in the lines of fig. 7, in which the horizontal ordinates, as usual, refer to time, and the vertical to the quantities of vapour absorbed. In this fig. the brown loam, and stiff white clay, which differ very considerably in general character, are very close together—the lines for the other soils are all distinct—those representing absorption by the cane-brake specimens rise steadily, and high above all the others.

N.—Absorption of gases by soils.

Direct experiments on the power possessed by dry soils, of absorbing permanent gases, into their pores, appear as yet to be wanting, although Schübler† has examined soils in the wet condition as to the special absorption of oxygen, and has drawn attention—as has also

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* The last line of numbers (weighings on the 20th day) are not represented, owing to the great length of the sheet which would be necessary; they would not materially affect the general character of the curves.

† Quoted in Hamm, Die Grundzüge der Landwirthschaft, i. 95. Brustlein (Ann. de Chim. et de Phys., t. ii. ch. vi. p. 165, quoted in Hoffmann; Jahresb. über die Fortschr. der Agricultur-Chem., 1859-60, s. 6) has also made a few experiments, on the absorption of ammonia by moist soil, and a single determination for dry soil.

Boussingault*—to the chemical effects which are produced by that gas when thus absorbed.

Gases directly or indirectly affecting the growth of plants, have often been spoken of, as either produced in the soil—*e. g.* carbonic acid by slow oxidation of organic matter—or introduced, solely in the form of solution in water, no notice being taken, of any capability on the part of the soil itself, to absorb permanently gaseous bodies.

I proposed at first to make some experiments on the absorption of carbonic acid gas, by the same method as that which I had applied to the absorption of aqueous vapour, namely, by weighing from time to time, a given portion of soil, exposed to an atmosphere of the gas. To do so, it was necessary to take the soil in a definite hygroscopic condition. That of complete dryness, produced by a temperature of 100 deg. C., would not answer the purpose, as, during the short time occupied in making the necessary weighings, the gain in weight by absorption of aqueous vapour from the air, would have seriously vitiated the results. It was then proposed, without sufficient forethought, to experiment upon the soil in a state of saturation, with hygroscopic moisture, and to keep it in this state, throughout the experiment, by exposure to an atmosphere of carbonic acid, in a closed vessel at the bottom of which there was a shallow dish of water.

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* Economie rurale, i. 609.

The experiments on this plan were begun, the specimens of soil used, being those (weighing originally 100 grammes each, when dry) which had been already employed for the absorption of vapour of water, and which had been pretty well saturated by exposure for twenty days to an atmosphere laden with moisture.*

The following were the first few weighings obtained:

	Soils all saturated with aqueous vapour (originally 100 grammes of each, dried at 100 deg. C.).						
	Cane-brake.		Brown loam.	Sand.	Red clay.	White clay.	Pine-woods soil.
	Surface soil.	Subsoil.					
	grms.	grms.	grms.	grms.	grms.	grms.	grms.
At commencement ……..	110.23	111.61	102.67	100.34	104.62	102.59	101.46
After 6 hours …………..	110.19	111.58	102.63	100.33	104.57	102.55	101.45
„ 12 „ …………..	110.15	111.51	102.57	100.32	104.48	102.52	101.45

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* *Vid.* Liebig, Poggendorff, and Wöhler, Handwört de Chem., Art. Absorption (2^{te} Aufl.), b. i. s. 23.

showing that the soils were actually *losing* instead of gaining weight. This result was due to the fact that, as the less absorbable carbonic acid entered the pores of the soil, it expelled more than an equal amount, of the more absorbable aqueous vapour, which had already been condensed there.

The above experiments were discontinued, and the following different method adopted. Each soil, slightly crushed, not pulverised, was dried at 100 deg. C., and 100 grammes were weighed out. This quantity was sewed up in a bag, made of very thin muslin, of about an inch in diameter, the absorptive power of which was found very small, and was allowed for. The little bag of soil, was again heated to 100 deg. C. for some time, to ensure its thorough dryness, and was then passed through mercury, into a glass jar previously filled with gas, carefully dried and accurately measured. In order that the bag might be withdrawn after the experiment, and the residual volume of gas measured, a thread was tied to the bag, and anchored under the mercury by a piece of platinum, so that gas could not creep along the fibres into or out of the jar. The soil remained in the gaseous atmosphere for six hours, the jar being gradually lowered as absorption took place, so that the pressure within, remained constantly that of the external atmosphere—in no case very far from 760 mm^{rs}. The temperature of the room was about 60 deg. Fahr. The gases experimented upon were oxygen, carbonic acid, and ammonia.

In all the experiments absorption took place to some extent; in general, the greater portion was over in the first two hours, and in every instance it seemed to have completely ceased before the end of six hours.

Some of the soils, when exposed to ammoniacal gas, absorbed so much that the jar had to be several times replenished. This was provided for by having other portions of gas, carefully measured off in jars, standing ready, in the mercurial trough.

The subjoined table gives the amounts, of the three gases which were absorbed by 100 grammes of each of the soils. The volumes of gas before and after each experiment, were reduced to 0 deg. C., and 760 mm^{rs}; the volumes given in the table, therefore, correspond also to this temperature and pressure.* The *weight* of gas absorbed has been calculated from the observed volume:

	Approximate volume of each 100 grammes of soil.†	Oxygen.		Carbonic acid.		Ammonia.	
		Absorption by volume.	Absorption by weight.	Absorption by volume.	Absorption by weight.	Absorption by volume.	Absorption by weight.
	c. c.	c. c.	grms.	c. c.	grms.	c. c.	grms.
Cane-brake { Surface soil	82	31.5	.0451	309.9	.6095	4277.1	3.2508
Cane-brake { Subsoil....	76	36.3	.0519	305.0	.5998	4872.4	3.7038
Brown loam............	81	15.3	.0219	104.6	.2057	887.2	.6743
Sand	68	3.9	.0056	14.4	.0283	139.4	.1059
Red clay..............	77	21.1	.0302	125.3	.2464	1044.7	.7940
White clay	77	13.9	.0199	87.2	.1715	824.9	.6270
Pine-woods soil	96	14.8	.0212	57.4	.1129	1108.6	.8426

The above numbers refer to the results of absorption by *equal weights* of soil. It seemed desirable to calculate the results for *equal volumes*, assuming the same rates of absorption to hold.

The second column of the above table gives the approximate volumes, in cubic centimètres, of 100 grammes of each soil in the dry state, as taken from the weighings made in connexion with experiments on the *rate of cooling* (*vide suprà*).

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* The fractional parts of a cubic centimètre to be found in the table result from this numerical reduction—in the gas-tube used such small amounts could not be measured.

† The weighings from which these volumes are deduced were made with *air-dried* soil, but will serve the present purpose for soil dried at 100 deg. C.

Using these numbers, we get by calculation the following table, in which the volume and weight of each gas are given, which 100 cubic centimètres of each soil would absorb:

Absorption by 100 c. c. of each soil.	Oxygen.		Carbonic acid.		Ammonia.	
	Absorption by volume.	Absorption by weight.	Absorption by volume.	Absorption by weight.	Absorption by volume.	Absorption by weight.
	c. c.	grms.	c. c.	grms.	c. c.	grms.
Cane-brake { Surface-soil…	[illegible]	[illegible]	377.9	[illegible]	[illegible]	[illegible]
Cane-brake { Subsoil………	47.7	[illegible]	491.3	[illegible]	[illegible]	[illegible]
Brown loam …………	18.9	.0270	129.1	[illegible]	[illegible]	[illegible]
Sand…………………	5.7	.0082	21.2	.0416	[illegible]	[illegible]
Red clay ……………	27.4	[illegible]	162.7	[illegible]	1358.8	[illegible]
White clay…………	18.1	[illegible]	113.2	[illegible]	1071.3	.8148
Pine-woods soil ……	15.4	.0221	58.8	.1176	1154.8	.8777

The preceding tables show that, of the three gases experimented on, oxygen is absorbed to the smallest extent, carbonic acid next, and ammonia in greatest amount. This is what we should expect from the relative condensability of the gases, if absorption were due solely to adhesive attraction. The large amount of oxygen which moist soils, rich in humus, may absorb, is, doubtless, chiefly due, to solution in water and chemical affinity. The various soils, however, do not agree in the relative quantities of oxygen, carbonic acid, and ammonia which they absorb: thus, the cane-brake soil absorbs decidedly less oxygen and ammonia, but a little more carbonic acid than the subsoil; the stiff white clay is superior to the pine-forest soil in power of absorbing carbonic acid, but inferior as regards absorption of ammonia—something like a special preference is shown by each soil for one or another of the three gases. The most striking result exhibited by the tables is *the prodigious power of absorbing ammonia possessed by the dry cane-brake soils.* It is not large merely by comparison with that of the other soils, though exceeding that of the most absorptive four or five times, but may fairly be called prodigious, when we remember that Saussure found the finest box-wood charcoal to condense ninety times its own volume of ammoniacal gas; the *cane-brake surface soil condenses fifty-two, and the subsoil sixty-four times its volume of that gas.**

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* One or two results obtained by Stenhouse—Ann. der Chem. u. Pharm., ci. 251—in the course of experiments upon the kinds of charcoal used for decolorising purposes, have perhaps a bearing upon this property of the stiff aluminous soils of the cane-brake. He found that 1 gramme of common wood char-

These soils also exhibit great, but not proportionate, eagerness in absorbing carbonic acid gas.

The special tendency to take up ammonia is most interesting, when looked at in connexion with the power of abstracting this substance from solution. This will be next examined.

O.—Absorption by soils of inorganic substances from solution.

Marked attention has of late been drawn by Liebig to the important observations of Way and others on the power possessed by soils of withdrawing from solution certain alkalies, salts, &c.; and our knowledge of the subject has been increased by the experiments which Liebig himself has instituted. This interesting property has been examined in the case of the specimens of cotton soil from the cane-

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coal absorbed 145 c. c. of ammonia, and 15 c. c. of carbonic acid, while the same weight of charcoal which had been soaked in solution of sulphate of alumina and ignited until the water and sulphuric acid were driven off, containing 7½ p. c. of alumina, absorbed 212.5 c. c. of ammonia, and only 12.5 c. c. of carbonic acid gas. In this case, however, there might be some suspicion of the retention of traces of sulphuric acid.

brake—want of time prevented the examination (which involved a good deal of labour) being extended to the other soils chosen for comparison of physical properties.

Solutions of the following six substances were prepared, all of the uniform strength—2 grammes of the substance dissolved to 1 litre of water:

Ammonia	2 grms. of	NH_3 in 1000 c. c. of water
Chloride of ammonium .	„	NH_4 Cl. ditto
Sulphate of ammonia .	„	NH_4O, SO_3 ditto
Nitrate of potash . .	„	KO, NO_5 ditto
Phosphate of soda* . .	„	$2 NaO, HO, PO_5$ ditto
Silicate of potash† . .	„	$_xKO, SiO_2$ ditto

Two portions, of 500 c. c. (containing, therefore, 1 gramme of the substance dissolved), of each solution, were placed in flasks, furnished with tightly-fitting corks. Into the one, 100 grammes of air-dried surface soil, slightly crushed, but not pulverised, was introduced; and into the other an equal quantity of the subsoil in the same condition. The flasks were corked, and set aside for twenty-four hours, agitating the liquid once every hour, for the first twelve hours. The solutions being undisturbed for the latter part of the time, were found nearly clear at the end of it; they were drawn off into clean flasks, again corked up, and allowed to stand until perfectly free from suspended matter.

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* 5.042 grammes of $2 NaO, HO, PO_5 + 24 HO$ were used, equivalent to 2 grammes of the salt without water of crystallisation.

† 2 grammes were found by analysis to consist of .6530 of SiO_2, and 1.3470 of KO.

The solutions of chloride of ammonium, sulphate of ammonia, and phosphate of soda, were very faintly acid to test paper, after they had been in contact with the soils; that of nitrate of potash seemed to be neutral; and that of silicate of potash was (before and after contact with the soil) alkaline.

The solutions had all, taken up lime and traces of magnesia from the soils; the amount of lime was very considerable in the cases of chloride of ammonium, sulphate of ammonia, and nitrate of potash; that is, of those salts which contained acids yielding soluble compounds with lime.

Accurately measured portions of the solutions, were then used to determine, the amount of dissolved substances still held in solution, which, thus by subtraction from the quantity originally dissolved, gave that absorbed by the soil.

I desired to determine, the proportions both of acid and base absorbed—this having only been done in *some* of the experiments already on record—and adopted the following methods:

Free ammonia was determined volumetrically, by a normal solution of oxalic acid.

In chloride of ammonium, the chlorine was determined as chloride of silver; the ammonia was expelled as gas, by heating with caustic soda, received in hydrochloric acid, and determined as platino-chloride of ammonium.

In sulphate of ammonia, the sulphuric acid was determined, as sulphate of baryta; the ammonia, by the method just mentioned, as platino-chloride.

In nitrate of potash, the nitric acid was determined, by the method of Pelouze as modified by Fresenius;* the potash, after removal of other bases, was precipitated as platino-chloride.

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* Treatment with a known amount of proto-chloride of iron, and subsequent determination by per-manganate of potash of the quantity of iron left as proto-chloride.

In phosphate of soda, the phosphoric acid was estimated as pyro-phosphate of magnesia; the soda as sulphate of soda, other bases having been removed.

In silicate of potash, the silicic acid was obtained by evaporation to dryness of the solution, with an excess of hydrochloric acid; the potash was determined by chloride of platinum, after the silicic acid had been separated by the filter.

The following are the results obtained:

AMMONIA.

After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Absorbed.......... .4798	1.0000	.7144......Absorbed.
Unabsorbed....... .5202		.2856......Unabsorbed.

In round numbers, of the ammonia present in solution,

The surface soil absorbed 48 per cent.
And the subsoil „ 71 „

CHLORIDE OF AMMONIUM.

	After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Chlorine.............	Absorbed... ... Unabsorbed .6703	.6635	.. Absorbed .6594 Unabsorbed
Ammonium (NH_4).	Absorbed ... .1704 Unabsorbed .1661	.3365	.1830 Absorbed. .1535 Unabsorbed

EQUIVALENT TO

Ammonia (NH_3)...	Absorbed... .1609 Unabsorbed .1569	.3178	.1728 Absorbed .1450 Unabsorbed

The difference between the amount of chlorine in the original solution, and that found remaining after the action of the soils, is so small (and in opposite directions for surface and subsoil), that this body is set down as unabsorbed.

Of the ammonium present, or its equivalent ammonia,

The surface soil absorbed about 51 per cent.
And the subsoil „ 54 „

SULPHATE OF AMMONIA.

	After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Sulphuric acid	Absorbed.... .0261 Unabsorbed .5800	.6061	.0754 Absorbed .5307 Unabsorbed
Oxide of ammonium (NH_4O)	Absorbed.... .2066 Unabsorbed .1873	.3939	.2454 Absorbed .1485 Unabsorbed
EQUIVALENT TO			
Ammonia (NH_3)....	Absorbed.... .1352 Unabsorbed .1224	.2576	.1605 Absorbed .0971 Unabsorbed

One or two experiments of Henneberg and Stohmann* seemed to show, that sulphuric acid is not absorbed at all, and the small amount which disappears after the action of the soils in the above results, might be attributed merely, to the slight solubility of the sulphate of lime formed. If, however, the unabsorbed ammonia be considered as still combined with sulphuric acid, the remainder of this acid would not produce more sulphate of lime, than the water present could hold in solution; moreover, the deficiency of sulphuric acid is greater, in the case of the subsoil, than of the surface soil, the former having in general the higher absorptive power. I am inclined, therefore, to believe, that absorption of the acid had really taken place, though the amount is small. Assuming this—

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* Annal. d. Chem. u. Phar., cvii. 152.

Of the sulphuric acid present,

The surface soil absorbed about 4 per cent.
And the subsoil „ 12 „

Of the oxide of ammonium, or its equivalent ammonia,

The surface soil absorbed about 52 per cent.
And the subsoil „ 62 „

Nitrate of Potash.

	After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Nitric acid........	Absorbed... .. Unabsorbed .4773	.5341	.. Absorbed .5343 Unabsorbed
Potash.............	Absorbed... .3082 Unabsorbed .1577	.4659	.3210 Absorbed .1449 Unabsorbed

The quantity of nitric acid, in the solution exposed to the action of the surface soil, appears to have diminished (the same result was obtained in a second experiment), but the diminution is, I believe, only apparent; a trace of organic matter dissolved out from the soil, reducing a little more per-manganate of potash, than would otherwise be effected; while the subsoil, wanting in organic matter, exhibits no such result. It may, therefore, be considered as shown, by these determinations, that nitric acid undergoes no absorption; this fact has not previously been brought to the test of direct experiment.

Of the potash present,

The surface soil absorbed 66 per cent.
And the subsoil „ 69 „

PHOSPHATE OF SODA.

	After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Phosphoric acid...	Absorbed... .3076 Unabsorbed .1924	.5000	.2729 Absorbed .2271 Unabsorbed
Soda..............	Absorbed... .1484 Unabsorbed .2882	.4366	.1990 Absorbed .2376 Unabsorbed

The experiments of Liebig* on the absorption of phosphoric acid, were made with solutions of phosphate of lime in carbonic acid water

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* Annal. d. Chem. u. Pharm., cv. 109.

Way* is said to have observed the withdrawal, of phosphoric acid from phosphate of soda, but the above are the first determinations I have seen, of the amount withdrawn from this state of combination.

Of the phosphoric acid present,

The surface soil absorbed 61 per cent.
And the subsoil „ 55 „

Of the soda,

The surface soil absorbed 34 per cent.
And the subsoil „ 46 „

SILICATE OF POTASH.

	After the action of 100 grammes of surface soil.	Originally in 500 c. c.	After the action of 100 grammes of subsoil.
Silicic acid........	Absorbed... .2932 Unabsorbed .0333	.3265	.2970 Absorbed .0295 Unabsorbed
Potash.............	Absorbed... .5454 Unabsorbed .1281	.6735	.6102 Absorbed .0633 Unabsorbed

Hence, of the silicic acid present,

The surface soil absorbed 90 per cent.
And the subsoil „ 91 „

Of the potash,

The surface soil absorbed 81 per cent.
And the subsoil „ 91 „

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* Quoted in Liebig, Poggendorff, u. Wöhler; Handw. d. Chem. (2^{te} Aufl.), b. ii. s. 229.

The above results are represented to the eye by fig. 8, A, B, C, D, E, and F. The rectangular space in each figure is divided by vertical lines into three equal parts, of which the middle one represents the composition of the substance originally present in solution, a horizontal line running across all three vertical columns, and dividing the space proportionally, to the relative amounts of acid (above the line), and base (below); the vertical division on the left, exhibits the absorptive effect of the surface soil, the space standing for the proportional amount of acid or base *absorbed* being of a darker tint than the rest; and the right-hand vertical division shows in the same way the effect produced by the subsoil.

In fig. 8, G (a repetition of A), H, and I, the same mode of representation is applied to comparing the relative amounts of ammonia, NH_3, absorbed, from simple solution in water, and from the solutions of chloride and sulphate; the fact being remembered, that in the cases of the salt, a less *absolute* quantity of ammonia was present in the solution, the same strength, 1 gramme to 500 c. c., having been adopted for these, and for free ammonia. The figures exhibit the per-centage amount, of the ammonia *present in each case* which underwent absorption.

J and K show the same thing with regard to potash in the nitrate and silicate respectively.

As to the degree of general absorptive power for salts, &c., which the foregoing results indicate as possessed by the cane-brake soils, it is not easy, in the present imperfect state of our knowledge, upon this subject of saline absorption, to form an exact opinion. The results which are already on record have been obtained by experiments made under various conditions as to quantity of soil, strength of solution, time of action of soil, &c.; but taking such cases as admit of use for purposes of comparison, there can be no doubt of the very high absorptive power possessed by the cane-brake specimens. Thus, Henneberg and Stohmann* found with regard to the calcareous soil of their experiments, from Weende, near Göttingen, that 100 grammes absorbed, from 200 c. c. of a solution containing .340 grammes of ammonia (=.850 grammes in 500 c.c.) after 24 or 168 hours of contact, about .095 grammes; and when a solution containing .680 grammes in 200 c.c. (=1.70 grammes in 500 c c.) was used, about .149 grammes was absorbed. In these experiments, then, under the conditions stated, the absorption of ammonia by 100 grammes was even from the stronger solution not more than one-third that of the cane-brake soil, or one-fifth that of the subsoil. Using a solution of chloride of ammonium nearly one-half stronger than mine (equivalent to .170 grammes NH_3 in 200 c. c., =.425 grammes in 500 c.c.), the absorption of ammonia was about one-third that of the cane-brake soils. The disproportion is even greater in the case of sulphate of ammonia.

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* Annal. d. Chem. u. Pharm., cvii. 159.

In the experiments of Brustlein,* the most absorptive earth examined, was that from Bechelbroun, and of this 50 grammes absorbed in 24 hours from 100 c. c. of a solution containing .355 grammes of caustic ammonia (= 1.775 grammes in 500 c. c.) .059 grammes (= .118 grammes for 100 grammes of soil)—one-fourth to one-sixth the amount taken up by the cotton soils. Compared in the same way, the Bechelbroun soil absorbed, from solution of chloride of ammonium, of more than half the strength used in my experiments, about one-fourth as much ammonia, and from a solution of six times the strength of mine a very little more ammonia than the cotton soil.

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* Annales de Chimie et de Physique, t. ii. ch. vi. p. 165, quoted in R. Hoffmann's Jahresbericht über die Fortsche d. Agricultur-Chem, 1859-60, s. i.

The experiments of Voelcker,* compared in the same necessarily imperfect way, indicate an absorptive power for ammonia of the soils examined by him, varying from one-half to one-fifth that of the cotton soil.

As to potash, Liebig† found that 1000 c. c. of the most absorptive soil examined by him—a plastic, loamy clay from Hungary—(= about 1.232 grammes) were required, when shaken up with a solution of silicate of potash (containing 1.183 grammes KO and 2.780 grammes SiO_3 to the litre), to destroy the alkaline reaction of 2855 c. c. of solution—hence the soil had taken up 3.377 grammes oi potash. This is equivalent to .274 grammes of potash absorbed by 100 grammes of soil, from a solution not quite as rich in potash as mine (.5915 grammes instead of .6735 grammes in 500 c. c.), from which 100 grammes of the cane-brake soil and subsoil absorbed .54 grammes and .61 grammes respectively.

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* Journal of the Royal Agricultural Society of England, xxi. 105.

† Ann. d. Chem. u. Pharm., cv. 109.

Comparing the two cane-brake specimens with each other, the power of (supposed) mechanical or adhesive absorption seems to be much stronger in the case of the subsoil than of that from the surface, as is indicated by the relative quantities of caustic ammonia withdrawn from solution; but when chemical decomposition also comes into play, the greater amount of lime in the surface soil, brings it nearer to an equality with the subsoil, and in one instance—that of the absorption of phosphoric acid—places it above the latter. It will be seen, by reference to the experiments of a few pages back, that the subsoil exceeded the soil, in power of absorbing ammonia, much more when this substance was in solution, than when it was in the gaseous state; in the latter case the two were more nearly upon an equality.

Comparing the relative quantities of ammonia absorbed in the caustic state, as chloride of ammonium, and as sulphate of ammonia, we find the numbers to be

	NH_3	NH_4CE	HN_4O, SO_3
Surface soil…………………	48 p. c.	51 p. c.	52 p. c.
Subsoil………………………	71 „	54 „	62 „

and, comparing in like manner the potash absorbed as nitrate and silicate, we find

	KO, NO_5	xKO, SiO_2
Surface soil…………	66 p. c.	81 p. c.
Subsoil………………	69 „	91 „

In no case did *complete* absorption of any soluble substance take place; the results therein agreeing with those of Henneberg and Stohmann, Brustlein and Voelcker.

It is remarkable that Liebig,* in attempting to prove the fallacy of the view generally held as to the mode in which plants obtain their mineral food, bases his argument upon these two positive statements,† that such substances as are indispensable articles of food for plants, are *completely* withdrawn by the soil from solution in water, and that rain-water filtered through soil, does not dissolve out *a trace* of potash, silicic acid, ammonia, or phosphoric acid. Both propositions are opposed to the quantitative results of all the experiments hitherto made.‡ If, in fact, arable soil possesses the power of absorbing, not the whole, but *a large proportion* of the ammonia, potash, phosphoric acid, &c., which water brings to it in solution, and of again yielding these absorbed substances to the solvent action of water, but

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* Letters on Modern Agriculture; edited by J. Blyth, M.D. London, 1859.

† *Ibid.*, pp. 30, 31, 34, &c.

‡ *Vide* Henneberg and Stohmann, Ann. d. Chem. u. Pharm., cvii. 152; Way, Journ. of Roy. Agric. Soc. of England, xvii. 123; Voelcker, ditto, xxi. 105; Brustlein, Ann. de Chim. et de Phys., ii. vi. 165; Verdeil and Risler, Dingler polyt. Journ., cxxvii. 388; Krocker, Annal. d. Preuss. Landwirthsch, xxii. 391; Zöller, Ann. d. Chem. u. Pharm., cvii. 27.

very slowly, should we not rather view this remarkable property as a most beautiful provision for the storing up and gradually supplying to plants the mineral food which they need, and which we may still assume to be taken up by their roots in the state of aqueous solution?

CHAPTER VII.

MECHANICAL ANALYSIS OF CANE-BRAKE SOIL AND SUBSOIL.

The necessity of presenting, in connexion with the chemical analysis of a soil, an accurate description of its texture, the coarseness or fineness of its constituent particles, &c., is repeatedly insisted on by writers upon agricultural chemistry, but unfortunately the suggestion is seldom fairly carried into practice. The state of division of a soil is generally mentioned but in loose and inexact terms—results of precise experiment, comparable with the observations of other experimenters, are not often given. It is much to be desired that some general agreement were established amongst analysts as to a precise method in common, of examining soils in this, as well as in other respects; the value of the mass of facts constantly accumulating would be much enhanced, if thus all were determined by the same uniform methods, and were, therefore, immediately and fully comparable with each other.

The great uniformity and very fine state of division, of the cane-brake soils, rendered their mechanical analysis a comparatively easy task: the following method was employed.

Of the fairly selected samples of soil and subsoil, portions of a kilogramme each, were taken in the air-dried state. Each specimen was, in the first instance, *boiled* with an excess of water until thoroughly disintegrated and reduced to a uniform thin mud; this was absolutely essential, and required two or three hours' boiling and frequent stirring, so great was the tendency of the fine plastic clay, to form and remain in clots or lumps. The creamy mud thus produced, was poured upon a sieve, which opened below upon a second, the second upon a third, the third upon a fourth, and the fourth upon a large funnel, which discharged all that had passed through the series of sieves into glass jars.

Of the four sieves, which were made of brass-wire gauze, the first had 36 meshes to the square inch, the second 100, the third 400, and the fourth 1600 meshes. *

The matter caught upon each of the sieves, was washed with water, to free it from adhering finer particles, dried in a steam-bath, and weighed; in order to get the proportion of organic matter, the latter might have been burned off, and the loss of weight determined, but the quantities of material collected upon the several sieves were so small, that there was no difficulty in picking out with a pair of forceps the grains of inorganic matter, from the little fragments of roots, leaves, &c.; this was therefore done, and the two were weighed separately.

The finer portion of the soil, which had passed through all the sieves, was treated according to the general directions of F. Schubze;† it was placed, as mud, in a conical vessel (the apex of the cone downwards) of

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* That is to say, the meshes were respectively 1-6th, 1-10th, 1-20th, and 1-40th of an inch on the side of the square.

† Journ. für prakt. Chem., xlvii. 265.

15 inches in height, and washed by a stream of water flowing through a tube which reached to the bottom of the vessel. The tube was $\frac{1}{5}$th of an inch (5 millimètres) in diameter, drawn out at the lower end to a diameter of $\frac{1}{25}$th of an inch (1 millimètre), and water was allowed to flow into a funnel at the upper end so as to keep the column of water in the tube constantly 2 inches (50 millimètres) above the level of that in the conical jar itself. A side tube, near the top of the jar, gave exit to the water laden with matter in the finest state of division; it flowed off into another vessel, in which all suspended matter was finally allowed to subside. The portions washed off and remaining after the washing process, were examined under the microscope, the organic matter was burnt off, and the loss of weight determined.

As the results of chemical analysis were calculated, for the soil, in various conditions of moisture or dryness, it seemed well to present the mechanical analysis in the same form; hygroscopic water, therefore, is included in the statement of the latter. This is particularly desirable in the case of these cane-brake soils, on account of the large amount of water which they are capable of retaining. The results of analysis have been calculated for the following cases:

1. The soil and subsoil as taken from the field, each containing, therefore, the amount of moisture due to its depth below the surface, in moderately dry, cool weather (*vide suprà.*).

2. The soil specimens in their air-dried state; that is, dried by mere exposure to the air of a room at 50 or 60 deg. Fahr.

3. The same dried at the temperature of boiling water, until they ceased to lose weight.

4. The same deprived of combined, as well as of hygroscopic water, and of organic matter—the fixed inorganic portion alone being considered.

The mechanical analysis, thus stated, presents the following results:*

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* Owing to the difficulty of getting large quantities of highly hygroscopic soil into the same condition of dryness, it was impossible to exhibit the exact loss or excess due to defective manipulation, which was, however, a small fraction of one per cent. The results are therefore calculated as for 100 parts of material used.

SURFACE SOIL, AS TAKEN FROM THE FIELD.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake soil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.35	Inorganic matter. (Hard fragments of clay, burnt black and red*—one or two small shells)...	.17	
		Organic matter. (Fragments of twigs, bark, root-fibres, &c.—one or two bits of charcoal*)...........	—	.18
Caught on sieve of 100 meshes to the inch.	.27	Inorganic matter. (Hard bits of burnt clay,* concretionary grains —oxide of manganese)...........	.16	
		Organic matter. (Fragments of twigs, bark, root-fibres, &c.—one or two bits of charcoal,* and seeds)................................	—	.11
Caught on sieve of 400 meshes to the inch.	.33	Inorganic matter. (As on sieve of 100 meshes, with one or two grains of quartz)....................	.12	
		Organic matter. (Fragments of twigs, bark, root-fibres, and leaves, a little charcoal,* and some seeds)	—	.21
Caught on sieve of 1600 meshes to the inch.	.43	Inorganic matter. (As on sieve of 100 meshes—some black, probably burnt, grains distinctly magnetic—a good many grains of quartz)...........................	.11	
		Organic matter. (As on sieve of 400 meshes)........................	—	.32
Residue from washing process, very finely divided, scarcely could be called sand.	20.02	Inorganic matter. (Appeared under the microscope as chiefly consisting of very minute grains of yellowish quartz)...............	18.07	
		Organic matter—(Particles of vegetable fibre, more or less decomposed)—with chemically combined water........................	—	1.95
Portion washed off—most finely divided.	53.61	Inorganic matter—(Clay and silica in a state of extreme division—a few infusorial skeletons) with portion soluble in water.....	47.19	
		Organic matter—(Particles of vegetable fibres)—with combined water, salts of ammonia, and other volatile matter	—	6.42
Water.	24.99	Water driven off at 100° C.......	—	6.82
		Water lost by free exposure to air	—	18.17
	100.00		65.82	34.18

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* *Owing* to burning of logs during the recent clearing of the land.

SUBSOIL, AS TAKEN FROM THE FIELD.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake subsoil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.05	Inorganic matter. (Concretionary grains of clay, limonite, oxide manganese)..........	.05	
		Organic matter.............	—	.00
Caught on sieve of 100 meshes to the inch.	.05	Inorganic matter. (As on sieve of 36 meshes).....................	.05	
		Organic matter....................	—	.00
Caught on sieve of 400 meshes to the inch.	.14	Inorganic matter. (As on sieve of 36 meshes, with one or two quartz grains).....................	.13	
		Organic matter. (Fragments of roots)............................	—	.01
Caught on sieve of 1600 meshes to the inch.	.35	Inorganic matter. (As on sieve of 36 meshes, with a good many little quartz grains. Some of the iron-shot particles pretty strongly magnetic)...............	.34	
		Organic matter. (Fragments of roots)..........................	—	.01
Residue from washing process, very finely divided, scarcely could be called sand.	25.38	Inorganic matter. (Extremely minute particles of yellowish quartz)............................	24.08	
		Organic matter—(Particles of vegetable fibre)—with chemically combined water...........	—	1.30
Portion washed off—most finely divided.	46.50	Inorganic matter—(Most finely divided clay, and excess of silica)—with matter soluble in water..............................	42.18	
		Organic matter—(Minute particles of vegetable fibre)—with combined water, salts of ammonia, and other volatile matter	—	4.32
Water.	27.53	Water driven off at 100° C.....	—	7.86
		Water lost by free exposure to air..................................	—	19.67
	100.00		66.83	33.17

SURFACE SOIL, AIR-DRIED.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake soil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.43	Inorganic matter	.21	
		Organic matter	—	.22
Caught on sieve of 100 meshes to the inch.	.33	Inorganic matter	.19	
		Organic matter	—	.14
Caught on sieve of 400 meshes to the inch.	.41	Inorganic matter	.15	
		Organic matter	—	.26
Caught on sieve of 1600 meshes to the inch.	.52	Inorganic matter	.14	
		Organic matter	—	.38
Residue from washing process.	24.46	Inorganic matter	22.08	
		Organic matter, with chemically combined water	—	2.38
Portion washed off.	65.51	Inorganic matter, including portion soluble in water	57.67	
		Organic matter, with chemically combined water, salts of ammonia, and other volatile matter	—	7.84
Water.	8.34	Water driven off at 100° C.	—	8.34
	100.00		80.44	19.56

SUBSOIL, AIR-DRIED.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake subsoil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.06	Inorganic matter	.06	
		Organic matter	—	.00
Caught on sieve of 100 meshes to the inch.	.06	Inorganic matter	.06	
		Organic matter	—	.00
Caught on sieve of 400 meshes to the inch.	.18	Inorganic matter	.17	
		Organic matter	—	.01
Caught on sieve of 1600 meshes to the inch.	.44	Inorganic matter	.43	
		Organic matter	—	.01
Residue from washing process.	31.60	Inorganic matter	29.98	
		Organic matter, with chemically combined water	—	1.62
Portion washed off.	57.88	Inorganic matter, including portion soluble in water	52.51	
		Organic matter, with chemically combined water, salts of ammonia, and other volatile matter	—	5.37
Water.	9.78	Water driven off at 100° C.	—	9.78
	100.00		83.21	16.79

SURFACE SOIL, DRIED AT 100° C.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake soil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.47	Inorganic matter..................	.23	
		Organic matter.	—	.24
Caught on sieve of 100 meshes to the inch.	.36	Inorganic matter..................	.21	
		Organic matter	—	.15
Caught on sieve of 400 meshes to the inch.	.45	Inorganic matter..................	.16	
		Organic matter	—	.29
Caught on sieve of 1600 meshes to the inch.	.56	Inorganic matter..................	.15	
		Organic matter	—	.41
Residue from washing process.	26.69	Inorganic matter..................	24.09	
		Organic matter, with chemically combined water............	—	2.60
Portion washed off.	71.47	Inorganic matter, including portion soluble in water.........	62.92	
		Organic matter, with chemically combined water, salts of ammonia, and other volatile matter..........................	—	8.55
	100.00		87.76	12.24

MECHANICAL ANALYSIS.

Surface Soil. Fixed inorganic portion considered separately.

Caught on sieve of 36 meshes to the inch............................	.26
Caught on sieve of 100 meshes to the inch..........................	.24
Caught on sieve of 400 meshes to the inch........................	.19
Caught on sieve of 1600 meshes to the inch........................	.17
Residue from washing process..	27.45
Portion washed off, including portion soluble in water............	71.69
	100.00

SUBSOIL, DRIED AT 100° C.

MECHANICAL ANALYSIS.

Separation of particles.	Proportionate weights.	Cane-brake subsoil.	Fixed constituents.	Combustible and volatile constituents.
Caught on sieve of 36 meshes to the inch.	.07	Inorganic matter..................	.07	
		Organic matter.....................	—	.00
Caught on sieve of 100 meshes to the inch.	.07	Inorganic matter..................	.07	
		Organic matter.....................	—	.00
Caught on sieve of 400 meshes to the inch.	.20	Inorganic matter..................	.19	
		Organic matter.....................	—	.01
Caught on sieve of 1600 meshes to the inch.	.49	Inorganic matter..................	.48	
		Organic matter.....................	—	.01
Residue from washing process.	35.02	Inorganic matter..................	33.23	
		Organic matter, with chemically combined water............	—	1.79
Portion washed off.	64.15	Inorganic matter, including portion soluble in water.........	58.20	
		Organic matter, with chemically combined water, salts of ammonia, and other volatile matter..............................	—	5.95
	100.00		92.24	7.76

MECHANICAL ANALYSIS.

Subsoil. Fixed inorganic portion considered separately.

Caught on sieve of 36 meshes to the inch..........................	.07
Caught on sieve of 100 meshes to the inch........................	.07
Caught on sieve of 400 meshes to the inch........................	.20
Caught on sieve of 1600 meshes to the inch......................	.52
Residue from washing process..	36.03
Portion washed off, including portion soluble in water...........	63.11
	100.00

The above results furnish striking evidence of the very fine state of division of these cane-brake soils. They contain no stones or gravel, scarcely any particles, in fact, of more than $\frac{1}{40}$th of an inch in diameter, since almost the whole passes through the finest sieve used, and, when washed, they yield a very high percentage (65—70 when dry) of impalpably fine matter. A slight increase of velocity, in the stream of water used for washing, would have borne along the whole of the sifted soil.

Such a uniform state of comminution—permitting the free passage of the roots in all directions, and presenting an enormous surface of the particles to chemical or solvent action—is of course highly favourable to fertility; indeed, in a paper published several years ago,* D. A. Wells attributed to this single cause the great fertility of "bottom" and "prairie" soils from the Scioto Valley, Ohio—a part of the rich grain producing region of the North-Western States—since, on examining these soils, he did not find them to present any marked superiority as to the chemical nature of their constituents, over others from New England, which were considered sterile.

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* American Journal of Science [2], xiv. 11.

From the statement made in this paper as to the result of sifting the specimens through a sieve of 60 meshes to the linear inch, it seems that the cane-brake soil of Alabama contains still fewer coarse particles.

The *enormous surface in proportion to mass presented by the particles* of a soil in a state of extreme sub-division, and its consequently high adhesive power, which enables gases, aqueous vapour, liquid water, and even soluble mineral salts, to be absorbed and retained in large amount, sufficiently explain the favourable effect upon vegetation.

CHAPTER VIII.

CHEMICAL ANALYSIS OF COTTON SOIL AND SUBSOIL.

MY intention being to make the chemical examination of these cotton soils as complete as possible, a method of analysis was adopted, based in general upon the directions of Fresenius,* departing, however, from these in some respects, especially as regards the quantities of soil used for the various experiments. Although the finely divided and uniform character of the cane-brake soil, causes a more than unusual probability of obtaining a fair average result from analysis conducted upon a small quantity, it is not well to trust this probability too far. In such a complex mixture as a soil, it is, I think, always desirable to take for examination a tolerably large amount; many soil analyses on record, made upon a few grammes of material abounding, perhaps, in coarse grains of sand and gravel, may not unfairly be set down as worthless, merely from want of precaution as to this fact. It is easy, from a soil, although itself far from uniform in character, to get a perfectly uniform mixture of all the more important constituents—those which are extracted by water or acids—if we simply prepare the solutions of these, from known and large quantities of soil, and then weigh or measure off such portions of the solutions as may be needed for the several determinations. Assuming even, that a soil is itself, absolutely homogeneous, it becomes necessary to use a large amount for analysis, if we would determine quantitatively, the constituents soluble in water, the sum of which amounts usually to but a small fraction of 1 per cent. of the entire mass. To determine accurately the minute quantities of phosphoric acid and the alkalies in aqueous, or sometimes even, in acid solutions, we must get weighings which are reliable in the fourth decimal place, as referred to 100 parts of soil; such numbers really mean nothing, if the determination have been made from only a few grammes of the original material.

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* In the last (German) edition of his "Introduction to Chemical Analysis." The valuable chapter by Otto upon soil analysis, in Sprengel's "Boden-Kunde," has been also frequently referred to.

The following course was pursued with the cane-brake soils. All the portions of air-dried soil used were weighed out at the same time, so as *to agree in hygroscopic condition.*

1. Water.

1000 grammes, of each of the soil specimens, was weighed off, at the time of collection from the field, and put up separately. Each sample was spread out, loosely covered with sheets of paper, and exposed to the air of a room at 50 to 60 deg. Fahr. (10 to 15 deg. C.), for several weeks, until it ceased to lose weight. The main bulk of the soil collected for analysis, having been in like manner "air-dried," 200 grammes, of the thoroughly mixed air-dried soil, was dried at the temperature of 100 deg. C., and the loss of weight determined. The same portion, was then kept at 150 deg. C., until it ceased to lose weight. It was finally heated to moderate redness, in a shallow dish of platinum foil, placed in a muffle, until all remaining water, salts of ammonia, &c., had been volatilised, and the organic matter had burnt off. After moistening with carbonate of ammonia, and gently re-heating, it was weighed.

2. Organic matter.

To determine, the (so-called) humic acid, ulmic acid, &c., a sample of 200 grammes, of most intimately mixed soil, was heated nearly to boiling for four hours, with 500 c. c. cold, of saturated solution of carbonate of soda and 500 c. c. of water; the solution was poured off, 250 c. c. of carbonate of soda solution with 500 c. c. of water were added, and this more dilute fluid, was heated for two hours more. After both solutions had been filtered, the mixed filtrates were precipitated by dilute hydrochloric acid, added up to incipient acid reaction. The precipitated humic acid was collected upon a weighed filter, dried at 150 deg. C., and weighed. It was subsequently burned, and the weight of ash deducted.

For the humus-coal, or humine with ulmine, &c., the portion of soil which had been already employed in determining the humic acid, was treated with 800 c. c. of moderately concentrated solution of caustic potash, nearly at the boiling point, for four hours, then with 200 c. c. of the same solution in addition for two hours more. From the decanted and filtered solutions, brown flocks of humus were precipitated by dilute acid, and as before filtered out, dried at 150 deg. C., weighed, burned, and the amount of ash deducted.

In calculating the results of analysis, the carbon of the humoid substances, is reckoned at 60 per cent., on the authority of Schubze.

The portion of soil from which the above substances had been removed, was treated with an excess of dilute hydrochloric acid, in order to drive off all the carbonic acid of carbonates, it was then washed, dried, and the remaining *carbon* determined by careful burning with oxide of copper in a stream of oxygen.* The carbon, was assumed to belong to root-fibres, &c., and the amount of such residual organic matter, was calculated for the subsoil, by allowing 44.44 per cent. of carbon, the proportion in cellulose ($C_{36} H_{30} O_{30}$). In the case of the surface soil, in which some particles of *charcoal* (derived from the burning of logs) had been observed, the carbon was reckoned at 50 per cent. of the undecomposed organic matter.

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* An attempt was made, with another portion of air-dried soil, to determine the carbon, by treatment with bi-chromate of potash

The trace of organic matter, set down as crenic, apocrenic, or some similar acid, was obtained by adding ammonia, to the solution from which humus-coal had been precipitated. Alumina had been dissolved by the caustic potash used, and remained in solution after the humus-coal had been separated by hydrochloric acid; this alumina, when thrown down by ammonia, carried with it a trace of organic matter.

A fresh portion of 200 grammes of air-dried soil, was treated with boiling alcohol of 90

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and concentrated sulphuric acid, the carbonic acid evolved, being collected in potash bulbs in the usual way. This method gave, in a single experiment, very fairly satisfactory results, and is convenient, on account of the large quantities of soil which can be thus treated.

p. c., in order to dissolve out any resinous matter. After filtration the liquid was evaporated nearly to dryness, cooled, and diluted with water. The trace of resin-like substance, thus obtained from the surface soil, was subtracted from the weight of humic acid found.

To estimate the ammonia, 500 grammes of soil, was mixed with milk of lime, and heated for several hours in a steam-bath, the expelled ammonia was received in dilute sulphuric acid, and volumetrically determined.

This method, however, was not found at all satisfactory. The evolution of ammonia became excessively slow, ere long, yet when the process was stopped, traces were still coming over. It seems impossible, although the contrary has been asserted by Mayer,* thus to determine the whole amount present in the soil.

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* Liebig, Poggendorff, and Wöhler; Handwört d. Chem. (2te Aufl. ii.), 252. Mayer used caustic soda to expel the ammonia. Knop and Wolff (in a paper which I have only seen in abstract) are said to have applied a new method, involving the use of a hypochlorite, to the determination of nitrogen in soils, and according to their results, *fertile soils do not yield appreciable traces of ammonia.*—Chemisches Centralblatt, April, 1860, pp. 244-247, quoted in the Répertoire de Chimie pure, October, 1860, p. 362.

The nitric acid was determined, in a separate aqueous extract, prepared from 1000 grammes of air-dried soil, by the mode described further on. As organic matter was present, it became necessary, to estimate the nitric acid by the method of Schlösing, as given by Fresenius. The process is troublesome, but yielded satisfactory results, when checked by experiments made in the same way upon known quantities of pure nitrate of potash.

The total amount of nitrogen present in the soil, was determined by elementary analysis, employing the method of Simpson; then, having subtracted the quantities of nitrogen contained in the ammonia and nitric acid, the remainder was set down as belonging to the unchanged vegetable matter.

The sum of all the organic substances found, being deducted from the weight lost, by the soil (previously dried at 150 deg. C.), on heating to redness in the air, the difference represented the water which had been retained with most tenacity.

3. Inorganic matter soluble in water.

2000 grammes of air-dried soil (in four separate portions of 500 grammes each) was treated with cold distilled water in the way recommended by Schubze; that is to say, each portion was placed in a percolator, delivering beneath into a Woulfe's bottle, from which the air could be partially withdrawn by an exhausting syringe. Water was poured on in small quantities, and allowed to remain in contact with the soil for several hours, before it was drawn through, by exhausting the air beneath. The process was continued for two or three weeks, until mere traces of saline matter appeared to be dissolved out; yet, nevertheless, the solution thus formed probably did not contain the whole of the matter which the soil was capable of yielding to cold water. Water passes through the cane-brake soil with such difficulty, that, if there be the least inequality of compactness in the material in the percolator, capillary channels may be established through the looser portions, and the liquid make its way through these almost exclusively, thus failing to exhaust of soluble matter, the less permeable parts of the mass.

The above process is, however, the only one, by which a clear aqueous solution can be obtained, in anything like a reasonable time;* no ordinary filtration through paper nor any process of decantation, will remove the excessively fine particles of suspended matter from the muddy water, which has been once mixed with the soil.

The aqueous extracts were mixed, evaporated to a moderate bulk, and divided by accurate measuring into separate portions, from which the various constituents were determined by the usual methods of analysis.

The phosphoric acid was precipitated by molybdate of ammonia, the precipitate re-dissolved in caustic ammonia, and the acid determined as pyro-phosphate of magnesia.

4. Inorganic matter soluble in hydrochloric acid.

One of the portions of soil (of 500 grammes in the air-dried state) from which the matter soluble in water had been removed, was heated over a water-bath, for several hours, with hydrochloric acid of moderate strength, under which treatment the lumps rapidly broke up, and complete disintegration took place; the greater part of the acid was poured off, and replaced by a fresh portion, which was again heated for some time. The solution was filtered, and the undissolved matter washed, without difficulty. The filtrate, mixed with the wash-water, was divided by measure, into separate portions, for the determination of the several substances in solution; larger quantities being used, for the estimation of such substances, as were present in small amount. The phosphoric acid was precipitated from this, as from the other solutions, by molybdate of ammonia. The other substances were determined by the usual methods.

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* A kilogramme of separate soil, treated in the same way, yielded the aqueous solution, from which the nitric acid was determined, as above stated.

A separate portion of soil, was treated with hydrochloric acid, in a flask filled with carbonic acid gas, and the solution thus prepared was tested for protoxide of iron; a trace only was detected in the case of the surface soil, and this may perhaps have been caused by the action of finely divided organic matter on the application of heat. A separate portion of air-dried soil, was also treated with very dilute nitric acid, at a gentle heat, and from this solution, the whole of the chlorine present, was precipitated by nitrate of silver; the quantity found in aqueous solution was then deducted. The considerable amount of chlorine, thus referred to acid solution, as compared with that dissolved out by water, is, I think, one evidence, that the latter had not thoroughly exhausted the soil of soluble matter. No power of withdrawing chlorine from solution by the soil itself, appears to be indicated by the absorption experiments.

5. Inorganic matter, decomposable by strong sulphuric acid.

The matter left undissolved by hydrochloric acid, was treated in successive portions, with mono-hydrated sulphuric acid, heated in a large platinum dish until it gave off copious fumes. After cooling, water was added to the mass, the whole was filtered, and the residue washed.

The substances dissolved in the filtrate, were determined from separate portions. The alumina still retained a trace of phosphoric acid. A little silicic acid had been dissolved; but a much larger quantity, separated from alumina, remained upon the filter, mixed with that which had been unaffected by sulphuric acid.

6. Inorganic matter, unacted on by sulphuric acid.

The material left upon the filter as just mentioned, was boiled with a moderately strong solution of carbonate of soda, and the silicic acid thus dissolved out, being determined, was set down as separated from alumina by sulphuric acid; a part of it may possibly have been free silica, in a state of excessively fine division.

The portion undissolved by carbonate of soda solution, or rather a sample of it, was fluxed with solid carbonate of soda, and was found to consist of silica, with a mere trace of alumina.

Analysed in the above way, the cane-brake soils yielded the following results, which were obtained in the first instance, for the specimens in their *air-dried* state, and were then calculated for the other conditions of moisture or dryness. The same per-centage amount of loss, due to the defects of experiment, which actually appeared upon the analysis of the air-dried soils, has been assumed, in the other calculated analysis; though the propriety of this assumption is doubtful, as it is impossible to say how otherwise the loss should be divided, as between organic and inorganic matter, water, &c.

SURFACE SOIL (CANE-BRAKE), AS TAKEN FROM THE FIELD.

CHEMICAL ANALYSIS.

INORGANIC MATTER					—	65.7464
Soluble in water.*	.1152	Silicic acid			.0014	
		Phosphoric acid			.0007	
		Sulphuric acid			.0005	
		Carbonic acid			.0431	
		Chlorine			.0020	
		Alumina			.0002	
		Protoxide (?) iron			.0003	
		Red oxide (?) manganese			—	
		Lime			.0571	
		Magnesia			.0079	
		Potash			.0007	
		Soda			.0013	
Soluble in moderately strong hydrochloric acid.	16.8504	Silicic acid			.1970	
		Phosphoric acid			.1515	
		Sulphuric acid			.0286	
		Carbonic acid			1.3716	
		Chlorine			.0060	
		Alumina			6.5379	
		Sesqui-oxide iron			5.1263	
		Protoxide iron			Trace	
		Red oxide (?) manganese			.0174	
		Lime			2.6865	
		Magnesia			.4185	
		Potash			.1693	
		Soda			.1398	
Decomposed by concentrated sulphuric acid.	26.5727	Silicic acid (dissolved by HO, SO_3)			.1648	
		Silicic acid (not dissolved by HO, SO_3)			18.4529	
		Phosphoric acid			Trace	
		Alumina			6.5194	
		Sesqui-oxide iron			1.1407	
		Lime			.0298	
		Magnesia			.1138	
		Potash			.0861	
		Soda			.0652	
Unacted on by sulphuric acid.	22.2081	Silicic acid			22.2081	
		Alumina			Trace	
	65.7464					
ORGANIC MATTER*					—	3.4172
			Amount of carbon.	Amount of nitrog.		
		Ammonia	—	.0056	.0067	
		Nitric acid	—	.0039	.0153	
		Humic acid	.9083	—	1.5139	
		Humus-coal	.0938	—	.1563	
		Crenic, Apocrenic, &c., in acids	Trace	—	Trace	
		Resinous matter (soluble in alcohol)	.0004(?)	—	.0006	
		Other organic matter	.8622	.1486	1.7244	
			1.8647	.1581		
WATER					—	30.3082
Water driven off at a red heat					3.7229	
Water driven off at 150 deg. C.					1.6003	
Water driven off at 100 deg. C.					6.8150	
Water lost at 10—15 deg. C. (50—60 deg. F.)					18.1700	
					99.4718	99.4718

* .0184 of organic matter soluble in water.

SUBSOIL (CANE-BRAKE), AS TAKEN FROM THE FIELD.

CHEMICAL ANALYSIS.

			Amount of carbon.	Amount of nitrog.		
INORGANIC MATTER					—	66.7734
Soluble in water.*	.0589	Silicic acid			.0011	
		Phosphoric acid			.0009	
		Sulphuric acid			.0003	
		Carbonic acid			.0224	
		Chlorine			.0013	
		Alumina			.0001	
		Protoxide (?) iron			Trace	
		Red oxide (?) manganese			Trace	
		Lime			.0298	
		Magnesia			.0020	
		Potash			.0002	
		Soda			.0008	
Soluble in moderately strong hydrochloric acid.	17.6686	Silicic acid			.0489	
		Phosphoric acid			.1898	
		Sulphuric acid			.0208	
		Carbonic acid			.0361	
		Chlorine			.0006	
		Alumina			10.0680	
		Sesqui-oxide iron			5.9255	
		Protoxide iron			—	
		Red oxide (?) manganese			.0045	
		Lime			.6126	
		Magnesia			.5025	
		Potash			.1733	
		Soda			.0860	
Decomposed by concentrated sulphuric acid.	23.1486	Silicic acid (dissolved by HO, SO_3)			.1793	
		Silicic acid (not dissolved by HO, SO_3)			15.3875	
		Phosphoric acid			Trace	
		Alumina			6.0593	
		Sesqui-oxide iron			1.1610	
		Lime			.0310	
		Magnesia			.0943	
		Potash			.1215	
		Soda			.1147	
Unacted on by sulphuric acid.	25.8973	Silicic acid			25.8973	
		Alumina			Trace	
	66.7734					
ORGANIC MATTER*					—	1.0138
		Ammonia	—	.0042	.0051	
		Nitric acid	—	.0009	.0037	
		Humic acid	.0692	—	.1152	
		Humus-coal	.0217	—	.0363	
		Crenic, Apocrenic, &c., in acids	—	—	—	
		Resinous matter (soluble in alcohol)	—	—	—	
		Other organic matter	.3793	.0334	.8535	
			.4702	.0385		
WATER					—	31.8159
		Water driven off at a red heat			2.6038	
		Water driven off at 150 deg. C.			1.6909	
		Water driven off at 100 deg. C.			7.8512	
		Water lost at 10—15 deg. C. (50—60 deg. F.)			19.6700	
					99.6031	99.6031

* .0074 of organic matter soluble in water.

SURFACE SOIL (CANE-BRAKE), AIR-DRIED.

CHEMICAL ANALYSIS.

INORGANIC MATTER					—	80.4400
Soluble in water.*	.1409	Silicic acid			.0017	
		Phosphoric acid			.0009	
		Sulphuric acid			.0006	
		Carbonic acid			.0527	
		Chlorine			.0024	
		Alumina			.0003	
		Protoxide (?) iron			.0004	
		Red oxide (?) manganese			—	
		Lime			.0698	
		Magnesia			.0096	
		Potash			.0009	
		Soda			.0016	
Soluble in moderately strong hydrochloric acid.	20.6163	Silicic acid			.2410	
		Phosphoric acid			.1854	
		Sulphuric acid			.0350	
		Carbonic acid			1.6781	
		Chlorine			.0073	
		Alumina			7.9991	
		Sesqui-oxide iron			6.2720	
		Protoxide iron			Trace	
		Red oxide (?) manganese			.0213	
		Lime			3.2869	
		Magnesia			.5120	
		Potash			.2071	
		Soda			.1711	
Decomposed by concentrated sulphuric acid.	32.5114	Silicic acid (dissolved by HO, SO_3)			.2016	
		Silicic acid (not dissolved by HO, SO_3)			22.5770	
		Phosphoric acid			Trace	
		Alumina			7.9764	
		Sesqui-oxide iron			1.3956	
		Lime			.0365	
		Magnesia			.1392	
		Potash			.1053	
		Soda			.0798	
Unacted on by sulphuric acid.	27.1714	Silicic acid			27.1714	
		Alumina			Trace	
	80.4400					
ORGANIC MATTER*					—	4.1809
			Amount of carbon.	Amount of nitrog.		
Ammonia			—	.0068	.0082	
Nitric acid			—	.0048	.0187	
Humic acid			1.1113	—	1.8522	
Humus-coal			.1148	—	.1913	
Crenic, Apocrenic, &c., acids			Trace	—	Trace	
Resinous matter (soluble in alcohol)			.0005(?)	—	.0007	
Other organic matter			1.0549	.1818	2.1098	
			2.2815	.1934		
WATER					—	14.8509
Water driven off at a red heat					4.5549	
Water driven off at 150 deg. C					1.9580	
Water driven off at 100 deg. C					8.3380	
					99.4718	99.4718

* .0225 of organic matter soluble in water.

SUBSOIL (CANE-BRAKE), AIR-DRIED.

CHEMICAL ANALYSIS.

			Amount of carbon.	Amount of nitrog.		
INORGANIC MATTER					—	83.2050
Soluble in water.*	.0735	Silicic acid			.0014	
		Phosphoric acid			.0011	
		Sulphuric acid			.0004	
		Carbonic acid			.0279	
		Chlorine			.0016	
		Alumina			.0001	
		Protoxide (?) iron			Trace	
		Red oxide (?) manganese			Trace	
		Lime			.0372	
		Magnesia			.0025	
		Potash			.0003	
		Soda			.0010	
Soluble in moderately strong hydrochloric acid.	22.0164	Silicic acid			.0609	
		Phosphoric acid			.2365	
		Sulphuric acid			.0259	
		Carbonic acid			.0450	
		Chlorine			.0008	
		Alumina			12.5455	
		Sesqui-oxide iron			7.3836	
		Protoxide iron			—	
		Red oxide (?) manganese			.0056	
		Lime			.7633	
		Magnesia			.6262	
		Potash			.2160	
		Soda			.1071	
Decomposed by concentrated sulphuric acid.	28.8450	Silicic acid (dissolved by HO, SO_3)			.2235	
		Silicic acid (not dissolved by HO, SO_3)			19.1740	
		Phosphoric acid			Trace	
		Alumina			7.5504	
		Sesqui-oxide iron			1.4467	
		Lime			.0386	
		Magnesia			.1175	
		Potash			.1514	
		Soda			.1429	
Unacted on by sulphuric acid.	32.2701	Silicic acid			32.2701	
		Alumina			Trace	
	83.2050					
ORGANIC MATTER*					—	1.2633
		Ammonia	—	.0052	.0063	
		Nitric acid	—	.0012	.0047	
		Humic acid	.0862	—	.1436	
		Humus-coal	.0271	—	.0452	
		Crenic, Apocrenic, &c., acids	—	—	—	
		Resinous matter (soluble in alcohol)	—	—	—	
		Other organic matter	.4726	.0416	1.0635	
			.5859	.0480		
WATER					—	15.1348
		Water driven off at a red heat			3.2446	
		Water driven off at 150 deg. C			2.1070	
		Water driven off at 100 deg. C			9.7832	
					99.6031	99.6081

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* .0092 of organic matter soluble in water.

SURFACE SOIL (CANE-BRAKE), DRIED AT 100° C.

CHEMICAL ANALYSIS.

INORGANIC MATTER					—	87.7996
Soluble in water.*	.1538	Silicic acid			.0019	
		Phosphoric acid			.0010	
		Sulphuric acid			.0007	
		Carbonic acid			.0575	
		Chlorine			.0026	
		Alumina			.0903	
		Protoxide (?) iron			.0004	
		Red oxide (?) manganese			—	
		Lime			.0762	
		Magnesia			.0105	
		Potash			.0010	
		Soda			.0017	
Soluble in moderately strong hydrochloric acid.	22.5025	Silicic acid			.2630	
		Phosphoric acid			.2024	
		Sulphuric acid			.0382	
		Carbonic acid			1.8316	
		Chlorine			.0080	
		Alumina			8.7310	
		Sesqui-oxide iron			6.8459	
		Protoxide iron			Trace	
		Red oxide (?) manganese			.0232	
		Lime			3.5876	
		Magnesia			.5588	
		Potash			.2260	
		Soda			.1868	
Decomposed by concentrated sulphuric acid.	35.4859	Silicic acid (dissolved by HO, SO_3)			.2200	
		Silicic acid (not dissolved by HO, SO_3)			24.6427	
		Phosphoric acid			Trace	
		Alumina			8.7062	
		Sesqui-oxide iron			1.5233	
		Lime			.0398	
		Magnesia			.1519	
		Potash			.1149	
		Soda			.0871	
Unacted on by sulphuric acid.	29.6574	Silicic acid			29.6574	
		Alumina			Trace	
	87.7996					
ORGANIC MATTER*					—	4.5634
			Amount of carbon.	Amount of nitrog.		
Ammonia			—	.0074	.0089	
Nitric acid			—	.0053	.0204	
Humic acid			1.2136	—	2.0217	
Humus-coal			.1253	—	.2088	
Crenic, Aprocrenic, &c., in acids			Trace	—	Trace	
Resinous matter (soluble in alcohol)			.0006 (?)	—	.0008	
Other organic matter			1.1514	.1984	2.3028	
			2.4903	.2111		
WATER					—	7.1088
Water driven off at red heat					4.9717	
Water driven off at 150 deg. C.					2.1371	
					99.4718	99.4718

* .0246 of organic matter soluble in water.

SUBSOIL (CANE-BRAKE), DRIED AT 100° C.

CHEMICAL ANALYSIS.

INORGANIC MATTER			—	92.2677
Soluble in water.*	.0815	Silicic acid	.0016	
		Phosphoric acid	.0012	
		Sulphuric acid	.0004	
		Carbonic acid	.0309	
		Chlorine	.0018	
		Alumina	.0001	
		Protoxide (?) iron	Trace	
		Red oxide (?) manganese	Trace	
		Lime	.0413	
		Magnesia	.0028	
		Potash	.0003	
		Soda	.0011	
Soluble in moderately strong hydrochloric acid.	24.4144	Silicic acid	.0675	
		Phosphoric acid	.2623	
		Sulphuric acid	.0287	
		Carbonic acid	.0499	
		Chlorine	.0009	
		Alumina	13.9120	
		Sesqui-oxide iron	8.1878	
		Protoxide iron	—	
		Red oxide (?) manganese	.0062	
		Lime	.8464	
		Magnesia	.6944	
		Potash	.2395	
		Soda	.1188	
Decomposed by concentrated sulphuric acid.	31.9868	Silicic acid (dissolved by HO, SO_3)	.2478	
		Silicic acid (not dissolved by HO, SO_3)	21.2624	
		Phosphoric acid	Trace	
		Alumina	8.3728	
		Sesqui-oxide iron	1.6043	
		Lime	.0428	
		Magnesia	.1303	
		Potash	.1679	
		Soda	.1585	
Unacted on by sulphuric acid.	35.7850	Silicic acid	35.7850	
		Alumina	Trace	
	92.2677			

	Amount of carbon.	Amount of nitrog.		
ORGANIC MATTER*			—	1.4009
Ammonia	—	.0058	.0070	
Nitric acid	—	.0013	.0052	
Humic acid	.0956	—	.1593	
Humus-coal	.0300	—	.0501	
Crenic, Apocrenic, &c., in acids	—	—	—	
Resinous matter (soluble in alcohol)	—	—	—	
Other organic matter	.5241	.0461	1.1793	
	.6497	.0532		
WATER			—	5.9345
Water driven off at a red heat			3.5980	
Water driven off at 150 deg. C.			2.3365	
			99.6031	99.6031

* .0102 of organic matter soluble in water.

SURFACE SOIL (CANE-BRAKE). FIXED INORGANIC PORTION CONSIDERED SEPARATELY.

CHEMICAL ANALYSIS.

Soluble in water.	.1742	Silicic acid	.0021
		Phosphoric acid	.0011
		Sulphuric acid	.0007
		Carbonic acid	.0652
		Chlorine	.0029
		Alumina	.0004
		Protoxide (?) iron	.0005
		Red oxide (?) manganese	—
		Lime	.0863
		Magnesia	.0119
		Potash	.0011
		Soda	.0020
Soluble in moderately strong hydrochloric acid.	25.4940	Silicic acid	.2980
		Phosphoric acid	.2292
		Sulphuric acid	.0433
		Carbonic acid	2.0751
		Chlorine	.0090
		Alumina	9.8917
		Sesqui-oxide iron	7.7560
		Protoxide iron	Trace
		Red oxide (?) manganese	.0263
		Lime	4.0646
		Magnesia	.6331
		Potash	.2561
		Soda	.2116
Decomposed by concentrated sulphuric acid.	40.2035	Silicic acid (dissolved by HO, SO_3)	.2493
		Silicic acid (not dissolved by HO, SO_3)	27.9187
		Phosphoric acid	Trace
		Alumina	9.8336
		Sesqui-oxide iron	1.7258
		Lime	.0451
		Magnesia	.1721
		Potash	.1302
		Soda	.0987
Unacted on by sulphuric acid.	33.6001	Silicic acid	33.6001
		Alumina	Trace
	99.4718		99.4718

SUBSOIL (CANE-BRAKE). FIXED INORGANIC PORTION CONSIDERED SEPARATELY.

CHEMICAL ANALYSIS.

Soluble in water.	.0880	Silicic acid	.0017
		Phosphoric acid	.0013
		Sulphuric acid	.0005
		Carbonic acid	.0334
		Chlorine	.0019
		Alumina	.0001
		Protoxide (?) iron	Trace
		Red oxide (?) manganese	Trace
		Lime	.0445
		Magnesia	.0030
		Potash	.0004
		Soda	.0012
Soluble in moderately strong hydrochloric acid.	26.3554	Silicic acid	.0739
		Phosphoric acid	.2832
		Sulphuric acid	.0311
		Carbonic acid	.0539
		Chlorine	.0010
		Alumina	15.0171
		Sesqui-oxide iron	8.8383
		Protoxide iron	—
		Red oxide (?) manganese	.0068
		Lime	.9137
		Magnesia	.7496
		Potash	.2586
		Soda	.1282
Decomposed by concentrated sulphuric acid.	34.5298	Silicic acid (dissolved by HO, SO_3)	.2676
		Silicic acid (not dissolved by HO, SO_3)	22.9525
		Phosphoric acid	Trace
		Alumina	9.0385
		Sesqui-oxide iron	1.7318
		Lime	.0463
		Magnesia	.1407
		Potash	.1813
		Soda	.1711
Unacted on by sulphuric acid.	38.6299	Silicic acid	38.6299
		Alumina	Trace
	99.6031		99.6031

In looking over these results, the necessity becomes obvious for exhibiting them with reference to more than a single condition of dryness, in order that they may be readily compared with other similar analyses; *both soil and subsoil as they were taken from the field, although not apparently in a wet state, contained nearly a third of their weight of water—and even when air-dried they retained about* 15 *per cent.*—this affecting proportionally the amount, as exhibited, of all other substances present.

But a very small per-centage, of *matter soluble in water*, is to be found in the analyses; this may in part be accounted for, by the imperfect washing of the soil by percolation, as already noticed, but a comparative experiment, made by *boiling* a quantity of soil with water until thoroughly disintegrated, and evaporating to dryness, the filtered but not perfectly clear solution, proved that the quantity of matter thus dissolved, was not very much greater than that extracted by percolation. The proportion in which the separate constituents were dissolved by water, agrees on the whole with the results of the experiments on saline absorption,

—lime and magnesia, as carbonates, were taken up in relatively large, potash and soda in small, amount; the latter alkali to a greater extent than the former. The quantity of phosphoric acid is larger than one would expect. The presence of a trace of alumina was distinctly ascertained, yet experience of the great difficulty with which such excessively fine clay can be removed from water by filtration, makes me suspect the possibility, of this alumina having been merely suspended, in a solution to all appearance perfectly clear.

The two acids employed are found to have attacked a very large portion of the soil, about 30 per cent. only, of the air-dried mass being left unaffected. *Alumina* and *sesquioxide of iron* are the substances dissolved in largest amount—the quantity of the former is unusually large—16 per cent. in all of the air-dried surface soil, and 20 per cent. of the subsoil. In this respect, these Alabama specimens resemble many of the Indian soils analysed by Messrs. Bernays and Manning for Dr. Forbes Watson.* Very few European soils exhibit so large a proportion of alumina. The presence of this earth is so directly connected with, and marks absorptive and retentive properties for water, as to render it far more important in soils situated under the climate of India, or the Southern States of America, than in cooler latitudes. The presence of a small quantity of oxide of manganese in the acid extract (and in the aqueous extract of the subsoil also) is in accordance with the results of Dr. R. Peter, who has shown that this metal is very generally diffused throughout the soils of Kentucky, of which he has examined a large number.*

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* Dr. J. Forbes Watson: Paper on the chief fibre-yielding plants of India, read before the Society of Arts, London, May

As to the substances directly needed as food by the cotton-plant, it has been shown in general by the ash analysis of Dr. Jackson,† that the principal are phosphoric acid, lime, magnesia, potash, and soda. All of these are

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9th, 1860. The soil analyses reported in this very valuable paper are specially suited for comparison with those here detailed, as the former refer to many of the principal cotton regions of India, and were made with special reference to the subject of cotton culture.

* D. D. Owen: 2nd and 3rd Reports of the Geol. Survey of Kentucky, 1857.

† U. S. Patent Office Report for 1857: Agriculture, p. 296.

present in considerable amount. But any statement as to the larger or smaller amount of such substances present in a soil, should be made with reference to the demands of the plant to be cultivated, and precisely here it is that our present knowledge is defective, not merely with regard to cotton, but to probably all cultivated plants. We frequently find appended to an analysis the statement—"This soil, it will be seen, contains an abundance of the mineral substances needed as food by plants;" but can any one say beforehand what *is* abundance of such bodies? What percentage of potash or phosphoric acid in a soil is sufficient for cotton, wheat, or any other crop, and what represents a deficiency? The sound and philosophic course of investigation marked out years ago by Liebig—in his so-called "mineral theory"—seems of late to have suffered in the estimation of many, not on account of any inherent fallacy, but because chemists have shrunk from the labour of fairly following it out, by multiplied and *exact* analyses of soils, made, not with the view of hastily determining for so-called "practical" purposes the good or bad quality of some particular soil, but with the object of finding out, in general, what—under given conditions of culture—is a good soil, and what a bad one. Bacon's "experimenta lucifera" have been here too much neglected for supposed "experimenta fructifera." Liebig himself has recently attempted* to estimate the minimum amount, of mineral food in the soil, which would suffice for the growth of a particular plant, such as wheat; basing his calculation, however, on the assumption that plants do not receive mineral food in the form of solution pre-existent in the soil, but only by direct contact with their roots. Admitting this, it is of course sufficient to know, the total surface presented by the roots of a plant, and the sum of the mineral substances which the healthy plant contains. But the assumption must at least be called, a very doubtful one, as has been noticed above in connexion with the subject of saline absorption; this phenomenon and that of capillarity, complicate excessively any estimate of the above character. The extent to which the roots of a plant penetrate the earth in all directions must, however, of course, have a direct bearing upon the proportion of mineral food in the soil essential to it, and in this respect the cotton-plant is favoured by Nature; its roots are long, especially the principal or tap-root. The results of a number of measurements, of cotton-plants which had attained their full growth, upon the spot whence the cane-brake soil was taken for examination, showed, that the average depth of the root from the surface of the ground was about 2 feet 1 inch, and the average lateral spread of roots (diameter of circle occupied) was about 2 feet 9 inches; hence we may conclude that a mass of about 5 cubic feet of soil, was more or less intimately penetrated.* The plants being placed at 18 inches apart, upon rows 4 feet apart, each root going down 2 feet was allowed 12 cubic feet.

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* Letters on Modern Agriculture, p. 110.

Returning to the consideration of the results of analysis, and taking as the best standard for comparison that of the Indian soil† of Dr.

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* More detailed measurements will be given in connexion with the future part of the work upon the chemical examination of the plant itself.

† Referring, apparently, to the air-dried condition.

Forbes Watson, it appears that *phosphoric acid* is present in larger quantity in the Alabama cotton soil than in any of the Indian specimens; the largest amount in any of the latter, being 0.166 p. c. for "good cotton soil of great extent, not manured," from between Panagurl and Jubbulpore, while the cane-brake surface soil contains altogether 0.1863, and the subsoil 0.2376 p. c.—the numbers here, as elsewhere, referring to the air-dried soil.

Lime is found in the Indian soils, to an extent varying from a mere trace up to 7.5, and in one instance 36 p. c.: the good cotton soils of Southern India appear to contain from 2 to 6 p. c. The total amount in the cane-brake soil from the surface is 3.3932, and in the subsoil 0.8391. Expecting to have found a larger proportion of lime in these soils, which directly overlie the soft "prairie limestone," I determined the amount, in two or three specimens taken from other parts, of the same plantation. The true "black soil" from the surface, gave uniformly about 3 p. c., but specimens taken from spots where the "bored rock" was found—small pebbles of it occurring in the portions analysed, yielded 8 p. c.; and a specimen containing numbers of little recent shells, gave as much as 15 p. c. of lime; these cases of unusual and merely local admixture of carbonate of lime, do not alter the general fact, that prairie soil, though overlying a very soft calcareous rock, is not itself composed to any large extent of carbonate of lime.

Magnesia constitutes about 0.200 to 2.000 p. c. of the Indian soils; in that from Alabama it forms 0.6608 p. c. of the surface, and 0.7462 p. c. of the subsoil.

The Indian specimens yielded *potash* in amount varying from 0.193 p. c. in the case of "fertile soil" from Lucknow—this being the specimen with extraordinary per-centage (36) of lime—to 2.240 p. c. in a soil from Mooltan —on an average, perhaps, from 0.500 to 1.500 p. c. The Alabama surface soil contains altogether but 0.3133, and the subsoil 0.3677 p. c.

Of *soda*,* we find among Dr. Watson's results, 0.043 p. c. in an "indifferent tea soil from close to the shore" of Assam, to 1.719 p. c. in the "good cotton soil," in which the maximum amount of phosphoric acid occurred, or an average about 0.500 to 1.000 p. c. The Alabama soil and subsoil yield respectively 0.2525 and 0.2510 p. c.

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* The experiments of Dr. Jackson (*loc. cit.*) showed that Sea Island, like Upland, cotton contains more potash than soda; the contrary had been supposed by some persons to be the case, it being imagined that a soil or atmosphere in the neighbourhood of

It is remarkable that so much of the potash and soda should have remained undissolved by hydrochloric acid, and appear only in the sulphuric acid solution.

The proportion of *organic matter* in the Indian soils is not separately stated, but is united with the water retained at 100 deg. C. This, of course, varies to a very large extent. The dark colour of the Alabama cane-brake soils, would lead to the expectation of finding a larger amount than is, in fact, present, though

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the sea, yielding an excess of soda to the plant, might cause the superior quality of the Sea Island staple.

Notwithstanding the fallacy of this supposition, it would seem that carefully conducted experiments with common salt or nitrate of soda as a manure for cotton would be well worth trying, in view of the recently published ideas of Liebig, as to what may be called the *digestive* rather than directly nutritive effect of chloride of sodium and other salts of soda and ammonia.

Vide Letters on Modern Agriculture, p. 60.

in the so-called "black cotton soil" of Southern India, Dr. Watson finds the organic matter and water lost above 212 deg. amount together to but 0.460 p. c. A large part of the organic matter in the Alabama soil is in the condition of soluble humus—this was to be expected—as cotton leaves or stalks fall upon the soil, they are ploughed in, and rapidly decay. As regards the *nitrogen* of the soil, the determination of *ammonia* is inaccurate, as was noticed in describing the method used—the ammonia as found being less than it should be, the nitrogen referred to residual organic matter, is in excess of the truth. The greater proportion of *nitric acid* than of ammonia in the surface soil if the determination of the latter could be relied on, would agree with the results of Brustlein's experiments.* The quantities of carbon and nitrogen, in both specimens examined, are to each other as 12 : 1 nearly.

The great power of absorbing and retaining *water*, is strikingly shown by the results of analysis. The Indian soils of Dr. Watson, if air-dried in London, probably retained a good deal more moisture, than they would have done for the same temperature in the atmosphere of Middle Alabama; yet none of them are said to have lost more than 6½ p. c. of water at 212 degs., except four specimens of the "black cotton soil," which yielded 10, 12, 16, and 17 p. c. The Alabama soil yields nearly 8½, and the subsoil nearly 10 p. c. On being heated to higher temperatures, the Indian soils lost, however, at the most 0.460 p. c. (organic matter included), while the Alabama soil gave up 6½ p. c. of additional water, and the subsoil nearly 5½ p. c. The resemblance between the "black cotton soils" of America and India as regards the large total amount of moisture contained, and difference between them as to the temperature at which it is given up, are worthy of notice.

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* Annales de Chimie et de Physique, t. ii. ch. vi. p. 165, quoted in Hoffmann's Jahresbericht über die Fortschritte der Agricultur-Chemie, 1859-60, s. viii.

Comparing the cane-brake soil and its subsoil together, the two appear to have very nearly the same general composition. The subsoil contains, of course, less organic matter, and this consists principally of unchanged root-fibres ; it contains less nitrogen in the form of nitric acid, as would be expected from its less exposure to atmospheric influence; it contains less of soluble silica, sulphuric acid, and chlorine, but more alumina, phosphoric acid, and potash. It is chiefly remarkable as containing less than a fourth of the amount of lime present in the soil of the surface, although nearer to the "prairie limestone" beneath.

As bearing upon the supply of lime to the cane-brake soils, I add the results of analysis of this "prairie limestone," cretaceous in age, which underlies the whole region; and also, of the "bored rock," which has been noticed in a former part of the paper as found in some places loosely strewn over the ground.

A.—"Prairie" or "Rotten" limestone. A soft, earthy mass—having when dry, about the tenacity of dense chalk—easily broken, exhibiting an imperfectly conchoidal shaly fracture—of pale yellowish white colour when dry, becoming dark yellowish grey when wet. Sp. gr. in mass=2.213—in powder=2.529.

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As bearing upon the supply of lime to the cane-brake soils, I add the results of analysis of this "prairie limestone," cretaceous in age, which underlies the whole region; and also, of the "bored rock," which has been noticed in a former part of the paper as found in some places loosely strewn over the ground.

A.—"Prairie" or "Rotten" limestone. A soft, earthy mass—having when dry, about the tenacity of dense chalk—easily broken, exhibiting an imperfectly conchoidal shaly fracture—of pale yellowish white colour when dry, becoming dark yellowish grey when wet. Sp. gr. in mass=2.213—in powder=2.529.

cimens of soil, were taken; the first was from Cahawba, about thirty miles farther east; and the third from Jones' Bluff, on the Tombigbee river, nearly as far to the west; hence, it would seem that the deposit becomes more calcareous in passing from east to west.

B.—"Bored rock." A tolerably dense and compact limestone, of light greyish yellow, or cream colour, in irregularly rounded masses, pierced with holes and cavities, of an inch or more in diameter, and breaking with uneven fracture. Sp. gr. in mass=2.655.

Analysis—

Carbonate of lime	95.35
Carbonate of magnesia	1.12
Alumina	.43
Sesqui-oxide of iron	.64
Alkalies	Faint traces
Phosphoric acid	
Insoluble in dilute acid (silicic acid, with a little alumina and sesquioxide of iron)	1.94
	99.48

CHAPTER IX.

GENERAL DEDUCTIONS FROM THE EXAMINATION OF ALABAMA COTTON SOIL.

In order to draw any useful conclusions from experiments, such as the above, upon a soil, the plant cultivated must be noticed, as well as some of the modes in which it is affected by climate.

A few remarks upon the cotton plant and its peculiarities with respect to climate must, therefore, be made here in anticipation of a future part of these researches.

The annual cotton, as cultivated in America, is a plant which attains its principal growth, in about four months, although it continues to develop seed and fibre, for a much longer period.

The extent to which its roots penetrate the soil has been noticed above, and from this some imperfect idea may be formed, of the power which it possesses of drawing upon the earth for nourishment, although no measure is thereby obtained, I think, of the capacity of the earth to *yield* nourishment,* as is shown by the experiments upon capillarity and saline absorption. Nor, indeed, do we even obtain any certain knowledge of the power with which the plant takes up its food from the soil; unless by microscopic examination, and by experiments such as those of Hales, some estimate be formed of the combined effects of capillary and osmotic action in drawing up liquids of various composition.

The special mineral food required by the cotton plant, and the amount of this food, remain to be examined by analysis of the ash, which will form another part of the investigation. Some statements with regard to the *nature* of the mineral constituents have been made, drawn from the results of Dr. Jackson's analysis, and all these substances needed by the plant, have been seen to exist in the soil. As to the *extent* to which they are withdrawn from the soil by cultivation, it may be remarked generally, that cotton is by no means an exhausting crop, under proper management.

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* On the assumption of Liebig—that mineral food is taken up only by direct contact with the roots—the surface exposed by the latter does become a measure, of the capacity of any particular soil to yield such nourishment.

The great mass of the plant—root, stem, branches, leaves, and emptied bolls—remains upon the field, and is ploughed into the soil, which is enriched by the rapid decay of the organic matter. Nothing is removed except the fibre and seed; and a large proportion, if not the whole of the latter, is by judicious planters* returned to the land—*cotton-seed* is, in fact, almost *the only material used as manure* in the cotton region of America; a large amount is added to the soil by the ordinary mode of sowing, the seed being thickly strewn by handfuls, in a continuous row, upon which, after thinning, but a few plants are allowed to remain. The *cotton fibre*, which constitutes the true saleable product, and is absolutely carried off from the land, must be looked upon as a very light crop; a bale of 400 or 500 lbs. to the acre, is sometimes obtained, under favourable circumstances; but this is much above the average for upland cotton. The fibre yields 1 or 1½ per cent. of ash, so that *at the most 7½ lbs. of mineral matter per acre will be removed from the soil annually.*

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* The practice of selling cotton seed from the plantation is one to be strongly deprecated. It is beginning to be common in some districts, owing to the increasing manufacture of cotton-seed oil, and exportation of the cotton-seed cake to Europe as food for cattle.

According to Johnston (Lectures on Agricultural Chemistry, p. 216), a crop of wheat of 25 bushels to the acre, removes from the soil, *in the grain alone*, about 17.65 lbs. of mineral matter; a crop of barley of 38 bushels carries off, *in the grain*, 46.98 lbs.; a crop of oats of 50 bushels, *in the grain*, 58.05 lbs. According to Liebig (Letters on Modern Agriculture, p. 41), an average crop of potatoes removes from each acre about 163 lbs. of mineral matter; and one of beet (leaves included) about 458 lbs.

With respect to climate. Cotton needs a high summer temperature, although not properly a tropical plant; it produces fibre in diminished quantity, though of improved quality, when removed from a southern locality to one farther north; it never seems to be directly injured by the most intense mid-day heat; when other crops, including even Indian corn, are drooping under a blazing sun, the large succulent-looking leaves of a cotton-field, will but seem to enjoy the congenial temperature. As is said by the writer of a pamphlet published by the Cotton Supply Association—"*cotton is decidedly a sun plant.*"

The proper supply of moisture, is a point of at least equal importance with temperature, and here appears undoubtedly to lie the main difficulty, hitherto experienced, in attempts to extend the culture of cotton into new regions. Published statements differ greatly as to the effect of moisture or dryness upon the plant, some writers affirming that a wet season is ruinous to cotton, and that drainage is of the first importance; while others—especially many of those treating of cultivation in India—insist that irrigation is more necessary than anything else. Dr. Royle* well says: "Such terms as moisture and dryness are so entirely comparative, that in one country we hear the cotton plant described as one requiring moisture, and in another we find it stated that no plant requires so little. The fact being, that the plant can bear both great heat and considerable want of water, provided it is growing in *a not over-dry atmosphere.*"

The last sentence states an important part of the truth, but, I think, not the whole; it draws a distinction between *two* forms in which moisture may be supplied to the growing plant, whereas it would seem that *four* should be separately noticed:

1. The *atmosphere* may contain a greater or less amount of water in the state of vapour, up to the so-called point of saturation.

2. The *atmosphere* may be super-saturated, or, in other words, precipitation of liquid water, as rain, &c., may take place from it.

3. The *soil* may contain a greater or less

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* Dr. J. Forbes Royle: On the Culture and Commerce of Cotton in India and elsewhere, p. 223.

amount of water, intimately united with it, whether by adhesion or in chemical combination; such water as is rapidly absorbed from the air by artificially dried soil, and can afterwards be expelled only by the application of a high temperature. This water does not render the soil moist to the touch. It can accumulate in a particular soil to a certain extent only, and this limit may be called the point of saturation of the soil.

4. The *soil* may be super-saturated; that is to say, liquid water, evident to the senses as such, may mix with the earth, and render it in the common sense of the term, moist or wet.

Now, it would seem that the larger the relative amount of water, in the first and third of these forms, taken up by the cotton plant, and the smaller the quantity received in the second and fourth forms (at least during the greater part of its period of growth), the more favourable will be the result.

In water-soaked soil—*i. e.* soil holding water in the fourth condition mentioned—cotton will not thrive. The following statements* are borne out by the general experience of planters: "The tap-root of the cotton plant will not strike down into wet soil." "On wet land the cotton plant grows small, looks sickly, or *scalds* in the hot sun, it bears but little raw cotton, and takes twice the labour to cultivate it, as the grass usually grows the faster around the plants, and is much more difficult to kill out." Such soil will obviously be benefited by draining.†

In the early stages of growth the plant receives a moderate supply of rain—*i. e.* water in the second condition named—with advantage; but even then, *heavy rains are very injurious, and later in the season they are absolutely destructive;* the bolls do not open, but fall off, or rot upon the branches, a surface growth of grass and weeds, accumulates so rapidly as to choke the crop, the "boll-worm" and other destructive insects make their appearance, and the cotton from such bolls as are already open, hangs out in trailing locks, draggled, dirty, and matted together. Dry years are emphatically those of the largest and best crops.

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* From the pamphlet, On the Cultivation of Orleans Staple Cotton, published by the Manchester Cotton Supply Association, p. 14.

† On the other hand, the state of things demanding artificial irrigation—very necessary, probably, in some parts of India—would seem to be simply the absence of water in any one of the three other conditions noticed.

Yet, like all other plants, cotton must be supplied with moisture; this even seems to be demanded in considerable quantity, judging from the extensive leaf-surface, from which evaporation is carried on. *Aqueous vapour in the air*, as suggested by Dr. Royle, and *abundant hygroscopic moisture in the soil itself*, as I would add, seem to be decidedly the sources from which this requirement is to be met.

The great advantage derivable, from a soil of high capacity for absorbing and retaining moisture, is that it will enable the plant, to withstand vicissitudes of weather and season; in damp weather hygroscopic water will be condensed, to be stored up in the retentive soil, until required in the times of drought, in August or September, when seed and fibre, are to be formed, and when, therefore, diminished leaf-activity is desirable, the roots will gradually draw up a supply of this water, limited no doubt,* but sufficient to maintain healthy life.

These remarks apply also to the absorption of gases, and of mineral matter withdrawn from solution, as has been noticed in a previous part of the work. The power of steadily accumulating and gradually dispensing, seems to be one of the well-marked and beautiful provisions, of the "*economy of Nature.*"

The soil of the prairie region of Central Alabama, fulfils the above conditions admirably, and to this fact, should I believe in large measure be attributed the success with which cotton is cultivated upon it.

To sum up the results of the examination of this fertile cotton soil, it is shown to be a stiff aluminous clay, containing moderate amounts of organic matter, and of the mineral substances needed by the plant as food—of great uniformity, and in an exceedingly fine state of division; above all, possessing a very high capacity for absorbing and retaining heat, moisture, gases, and soluble mineral matter.

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* The porous, chalky substance referred to as "rotten limestone," which underlies the soil of the cane-brake, has itself very similar capillary and absorptive power—it is penetrated by sandy strata, through which water can readily flow, and hence it is not at all inconceivable, that supplies of moisture, may be drawn up even through this from the depth of 20 to 30 feet, at which the first sandy bed is often found.

CHAPTER X.

MECHANICAL TREATMENT OF COTTON SOIL, AS PRACTISED IN ALABAMA.

In order to complete the subject of Alabama cotton soil, it seems desirable, that to the preceding results should be added, a brief statement of the way in which this soil is usually cultivated, which may easily be done in a few paragraphs.

As early in the winter, as the weather is favourable, and the condition of the ground suitable, *i. e.* when not too wet,* the preparation for the crop commences by "bedding the land." This is done by running a narrow plough, called a "bull-tongue," at regular intervals, across the field, the common distance between the rows, being four feet. In very rich alluvial land, the distance is sometimes five or even six feet, and in the poor land not more than three feet. Upon the furrow thus produced, the ridge or "bed" is made, by ploughing towards it, on either side, with a turning plough, called a "Carey" plough, drawn by two mules or horses, until the space between the rows has been ploughed out. The whole field is in this way thrown into ridges, which should run horizontally, round any elevated portions of the plantation, so that heavy rains may not wash away the soil.

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* The peculiar condition of the "cane-brake" soil (to which the above remarks apply), intermediate between a dry and a thoroughly wet state, in which alone, ploughing can well be carried on, has been noticed in an earlier part of the work.

When the time for planting arrives—viz. about the beginning of April—a furrow is run along the top of each ridge, by a narrow plough, and in this furrow the cotton seed is pretty thickly strewn, by hand, as the labourer goes along the row.

The seed is then covered with earth, by a heavy wooden block,* which a mule or horse draws along, so as not only to cover up the seed, but to press the earth firmly upon it.

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* Roller.

If the weather be favourable for the germination of the seed, it comes up in ten days or a fortnight, and soon afterwards the cultivation commences, by thinning out the cotton with hoes, so as to leave but a few stalks, together, at intervals of eight or ten inches, removing also any grass or weeds which may have grown with the cotton. The space between the rows, is at the same time ploughed, to make the earth light and mellow, and to destroy grass and weeds. Great skill is shown by trained negroes, in the use of the plough and hoe; the former is often run within two inches of the cotton, and the latter used, to cut out a weed, at a blow, within an inch or even half an inch of a plant, without in either case injuring the cotton plant itself. The process of cleansing the crop from weeds with plough and hoe is continued at intervals of three weeks, and at each time of thus going over the field the cotton is thinned out, until it is brought to a "stand"—that is, reduced to single stalks 12 or 18 inches apart upon the rows. Early in

July the plant has usually acquired sufficient size to shade the ground and prevent the further growth of grass, and the crop is then "laid by." It is of the first importance, that the land should have been kept perfectly clear of weeds, up to this time; and in a hot climate, the task is often a difficult one.

Simultaneously with the cultivation of cotton, the production of Indian corn, sweet potatoes, &c., is carried on, in order to furnish food for the negroes of the plantation, for the mules, or other draught animals, and for a sufficient number of hogs, to yield flesh meat, for the labourers.

In Middle Alabama, the cotton plant usually commences flowering, early in June, and continues to bloom until frost kills it. The bolls continue, therefore, to form during several months. The earliest bolls open, from the 10th to the 15th of August, in ordinary years, when the "picking" season commences. This lasts until the cotton is all gathered—until January or even February, if a full crop be made. The bolls continue gradually to open, long after frost has prevented the formation of any more. In picking the cotton from the boll, surprising manual dexterity is shown, by negroes accustomed to the task from early youth.

The seed cotton, as it is collected into large baskets by the pickers, is carried to the "gin-house" of the plantation, and "ginned," and, when enough of the clean fibre has accumulated, a day or two is devoted by a part of the hands, to pressing it with the large wooden "screw" into bales, ready for shipment by river, to the seaport.

THE END.

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